SOYBEAN PRODUCTION, PROTECTION, AND UTILIZATION

Proceedings of a Conference
for Scientists of Africa,
the Middle East, and South Asia

Sponsored by the International Soybean Program, INTSOY, and the Ethiopian Institute of Agricultural Research with support of the United States Agency for International Development.

International Soybean Program
INTSOY

International Agricultural Publications INTSOY Series Number 6
COLLEGE OF AGRICULTURE / UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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Proceedings of a Conference for Scientists of
Africa, the Middle East, and South Asia

October 14-17, 1974
Addis Ababa, Ethiopia

Edited by
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International Agricultural Publications
INTSOY Series Number 6

March 1975

Sponsored by the Ethiopian Institute of Agricultural Research
and the International Soybean Program (INTSOY), a cooperative
program of the University of Illinois at Urbana-Champaign and
the University of Puerto Rico, Mayaguez Campus. Supported by
U.S. Agency for International Development and conducted under
provisions of Contract AID/cm/ta-c-73-19 and AID Grant ta-g-1151.

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FOREWORD

The committee that was responsible for planning the Addis Ababa Conference on Soybean Production, Protection, and Utilization set forth four major objectives:

1. To encourage the exchange of information on soybean research, production, protection, and utilization between and among interested scientists from the region and around the world.
2. To interface with scientists of the region who are doing soybean work in their respective countries.
3. To discuss the nutritional benefits that may be realized, and the many useful products that can be derived from the soybean.
4. To inform the region's scientific, ministerial, and other appropriate persons concerning INTSOY's operations, interests, and expertise in the development of broadly conceived interdisciplinary programs in soybean research, production, protection, and utilization.

In planning for such a conference, there is the inevitable question: How many and who will judge the program to be sufficiently important to warrant the expenditure of time, energy, and travel costs? Other questions arise, both during and following the conference, concerning the degree to which the objectives are being or were attained.

This conference was visualized as a catalyst to a continuing process of technical exchange among those interested in soybean research, education, and development. The reason for publishing these Proceedings is to contribute to this process. Therefore, it is expected that the full impact and benefits of the conference can be judged only after some indefinite period of time.

Response to an evaluation questionnaire showed that the participants were well satisfied with the conference. Many valuable suggestions for future meetings were received. There were 97 participants from 27 countries, all of whom paid a registration fee. Except for those giving invited papers, travel and other costs were paid by the sponsoring government, university, or research institute, or by the individual himself. The support of these organizations and individuals is gratefully acknowledged.

The conference participants and those who find these Proceedings of value owe their appreciation to many, including the Ethiopian Institute of Agricultural Research, the Ethiopian Nutrition Institute, the Debre Zeit Agricultural Experiment Station, and the United States Agency for International Development, upon whose financial support the conference greatly depended.

We wish to express our thanks and appreciation to Sandra Osterbur, who typed the final draft for the printer, and to Lorena Neumann, who served as manuscript editor and production chief.

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Director
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October 14-17, 1974

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Soybean Research — More Food for More People

G.K. Parman

As the representative of the Agency for International Development, it is my real pleasure to welcome you to this workshop, and as a professional food scientist, my personal pleasure to be able to attend.

Research is the cornerstone of the AID agricultural program. We believe that research can provide truly great benefits and this belief is backed by the tremendous benefits that agricultural research, conducted mainly over the past 70 to 80 years, has brought to the United States. This research has resulted in a payoff of several tens of thousands of dollars for every dollar spent on research. Many of the countries in this world are in an analogous position now, and research, with emphasis on national research institutions, will certainly pay off in the same manner. It is an area that national planning cannot neglect without danger to national growth and development.

Our research program in AID is not carried out in an ivory tower. We rely on our great agricultural universities, and we insist that their work be carried out in close cooperation and collaboration with national and international research centers. We also encourage the fullest possible exchange of research data, through reports, correspondence, and, importantly, seminars such as this where scientists from a wide region can meet to share data, results, materials, and problems. We are looking to arouse the same spirit of creative research, well supported by the various governments, to build--in an idiom suited to each country--the program of beneficial research in agriculture that benefitted our own country. This program is international in that it draws from, and contributes to, programs in all countries, but national in that it focuses closely on national problems.

Soybeans are one of the major crops on which AID is focusing. We are interested in this crop because it can produce the highest yield of protein per unit of land area of any plant or animal food source, while at the same time producing calories. While it has been considered an industrial crop, it can be equally well used directly for human food. During the course of this seminar you will not only review the crop from the improvement-production standpoint but you will be shown, and have the opportunity to taste, a variety of highly acceptable food products made from the whole soybean. The processes used can be carried out in the rural farm home, and are also adaptable to small-scale village production and thus are a foundation for a budding agroindustry.

The ability of the soybean to provide its own nitrogen requirements through symbiotic nitrogen-fixing bacteria, *Rhizobia*, and to leave a generous amount of nitrogen for a subsequent crop is of equal interest in this period of disastrously rising fertilizer prices. This alone could make the crop important and it becomes a key factor in the development of cropping systems keyed to limited inputs of fertilizers and other chemical agents.

The peculiar need of the soybean to be adapted to very precisely defined regional climates and conditions requires--indeed demands--that the ultimate refinement of varietal research and production techniques must be carried out in the particular country. Thus, among many advantages, the crop is a good subject for national programs.

I think that we have an exciting seminar ahead of us, on a topic that can have a significant impact on the problem of feeding this island earth, our lonely and very precious home.

G. K. PARMAN: Food Processing Specialist, Office of Agriculture, Technical Assistance Bureau, Agency for International Development, Washington, D.C.

Soybeans and People

O.G. Bentley

Mr. Minister, delegates to the Regional Soybean Production, Protection, and Utilization Conference, special representatives from the sponsoring agencies, guests, ladies and gentlemen.

Mr. Minister, we deeply appreciate your warm and generous welcome to Ethiopia and to this important conference that deals with the all-important subject of food production and the modernization of agriculture. My colleagues from the United States, including, of course, those from the institutions I represent--the University of Illinois, Urbana-Champaign, and the University of Puerto Rico, Mayaguez--are proud indeed to share in this program. We hope the discussions of the potential of soybeans will ultimately lead to increased food production, especially for countries of the African continent.

It is fitting, too, that a conference of agronomic experts interested in science and technology as it relates to food production should be assembled in this great capital city under the sponsorship of the Ethiopian Institute of Agricultural Research in cooperation with other distinguished research agencies throughout the world.

The sponsoring organizations have set an ambitious agenda for this conference. The hope is that through the discussion and the formal presentations of the next four days we will gain a better understanding of the current "state of the art" of soybean production technology in this region of the world. Furthermore, the discussions should help to identify knowledge gaps and research needs and at the same time sharpen the focus for additional testing programs needed to determine the potential of soybeans as a food crop for this area of the world.

As a preface to my remarks about soybeans and their potential, it may be useful to reflect upon some general observations relating to agricultural development and the current food situation, particularly as applied to countries seeking to develop their agricultural industries.

As new crops or, for that matter, major agricultural development programs are being considered, it is important that the relationships of these endeavors to the broader areas of concern be given careful attention--for example world food needs and the impact these developments would have on possible strategies for dealing with this increasingly grave problem. We fully recognize that the increased demand for food is coupled with the expanding world population and the need to improve the general quality of the diets of people, especially for vulnerable segments of the population now experiencing hunger and the debilitating effect of malnutrition.

Demographic data on world population trends indicate that the rate of increase in population is approximately 70 million people annually. These figures, translated into future projections, give rise to the prediction that the world population could double by the year 2000 if current trends are maintained. These projections suggest the enormity of the world food problem facing developed and undeveloped countries alike, thus placing a sense of urgency on the nature of the proceedings that we are about to begin here in Addis Ababa.

Running parallel to the ever upward movement in population trends have been studies on world food production. During the past decade there have been many encouraging signs that total food production has been increasing, but the sobering development is that there appears to be a downward turn in production on a per caput basis. The Food and Agriculture Organization stated recently that the per caput availability of food on a worldwide basis was 3 percent lower in 1972 than the average level of food supplies available per individual during the five years from 1968 to 1972. While a one-year downturn may be coupled with catastrophies such as drought, lack of energy supplies, fertilizer, and other production inputs, the trend

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O.G. BENTLEY: Dean, College of Agriculture, University of Illinois, Urbana-Champaign.

showing that the ratio of population to food supplies is increasing is a warning that urgent steps must be taken to improve supplies and control population in an effort to achieve a more favorable food-to-people ratio.

On the supply side the obvious strategy for meeting the food need is to increase agricultural production and hence food supplies. There are, of course, many issues involved in accomplishing this objective, including substrategies aimed at better utilization of land, labor, and capital, and increasing the availability of production inputs. One of the heartening developments of the past decade has been the funding and establishment of international research centers with the mission of conducting research aimed at achieving greater production of basic food crops. These developments are not unrelated to the objectives of this conference--namely, evaluating the potential of soybeans and alternative methods of agricultural production, aimed at increasing the supply of high quality protein and edible oil for direct human consumption.

Accelerating agricultural production involves a great deal more than the agricultural sectors of the countries involved. There are important political, economic, and social decisions that have a direct bearing on the progress of agricultural modernization in every country, and including, of course, the less developed countries. The impact of changes is not restricted to the less developed countries. Countries having highly developed agricultural industries may have to reevaluate their agricultural production practices in terms of recent developments in energy, the increased costs of production inputs such as fertilizers, and because of competition for land, capital, and labor. Coupled with the foregoing, countries, including those with the agricultural capacity to produce food and feed grains and livestock products that can go into world trade, must balance the impact of such export trade on domestic demands and the potential these sales will have for their own food prices, balance of payments, and so on. The willingness of food exporting nations to share food on any basis through sales or on a concessional arrangement, and to commit nations to food aid programs, will be affected by supplies and the price of food domestically.

As we consider the introduction of soybeans as a new crop we are dealing with a major change in agricultural patterns--and, in fact, contributing to a process of change--in the hope of increasing the productivity of agriculture. The changes that a new crop can bring into the agricultural economy may have economic, political, social, and cultural implications, particularly if the crop is competitive with the existing crops or could lead to expansion of cultivated land. Agricultural changes in many countries can affect a major part of the population because as much as two-thirds to three-fourths of the population are engaged in farming and the care of livestock. Also, in many instances subsistence agriculture means poverty, which adds to the problems of cultivators seeking to break out of traditional roles.

In the process of modernizing agriculture--however beneficial to the long-term goals--we must take into account the social costs of change. The process must take precautions to minimize the impacts, particularly those that are detrimental to the lifestyle of the family engaged in agriculture. The benefits of change and modernization should accrue to the agricultural sector but at the same time contribute to the economic growth of the society as a whole. This means that the process of modernization in agriculture should be considered as a "total package," that is, in terms of increased economic employment opportunities, improved land use patterns, and changes that recognize traditional trade and barter relationships but that result in increased flow of economic benefits, not only to the agriculture sector but to the nation as a whole.

It is apropos to interject the observation that all too often a shortcoming of agricultural development programs has been the failure to recognize the importance of the agricultural infrastructure needed to support a new technology or a strategy of improving the productivity of agriculture. The infrastructure provides for research and education, credit, transportation, markets, marketing systems, processing and storage of food, and, of course, a food distribution system that brings the products to the people who will ultimately consume them. It may be provided by the public or private sectors but the critical need is for the services to be made available on a timely and economically feasible basis. Implicit, too, in a favorable "economic environment" for agriculture are incentives for farmers aimed at creating a positive attitude toward the use of the new technology and demonstrating to the cultivator that increasing productivity will bring financial and other rewards to those taking the economic risks to increase production.

One way of summing up the comments I have made is to say that agricultural developments can be greatly enhanced if the strategy for changing from traditional agriculture to new types of production is founded on a "systems basis." This viewpoint can be illustrated by

noting that the great break-throughs in production of crops such as wheat, rice, maize, and millet--often referred to as the "green revolution"--became possible because a new bundle of technologies have been developed and properly "orchestrated" in their application by cultivators in a manner that increases the returns to the farmers' land, labor, and capital. Without proper incentives cultivators will be reluctant to depart from old, tried-and-true systems of production and society will be the loser--the cultivator will not get the increased benefits for his labor and initiative, and the nonfarm sector of the society will not have the benefits of increased food production.

The foregoing comments lead me to emphasize that education and knowledge, linked with a sensitivity to understanding the processes of change, are of paramount importance in agricultural development and to the process of increasing the production of food and the more effective utilization of the food-producing capacities of the world.

The economic well-being of a nation, including growth in all sectors of its economy, may depend upon the well-being of its agriculture. Many of a nation's basic resources are allocated to agriculture--land, water, and capital. While there are many facets in the strategies for using these resources to the benefit of the people of every nation, one important function often neglected or relegated to a minor role is education and research and their relationship to agricultural development. New practices must be built on research, and developers must strive to gain an understanding of the relationships between changing technology and existing levels of understanding. These elements, in turn, must be related to agri-climatic conditions, and finally to the impact that change in production practices and other factors may have on marketing, processing, and utilization of food in human diets.

Now, let me turn to the central thrust of this conference, namely, soybeans--production, protection, and utilization. The topic is not unrelated to my earlier comments on modernizing agriculture and the importance of new looks at the age-old business of farming.

While soybeans are an old crop in the Far East, and a highly successful modern-day crop in the United States and Brazil, they must be considered a "new"--and largely unproved--crop in many regions of the world, particularly the tropic and subtropic belts. A move toward increased soybean production will require the introduction of new technology. And, in turn, that introduction will generate a need for a solid, well-founded educational program.

It is imperative that all agriculturists--those in research and in government, as well as producers and change agents--recognize that soybean production is a continuum that only begins with farmers. It does not end until the product is put to use in the country in which it is grown or has entered world trade. It would be an utter fallacy in planning and a great injustice to the producer if all of the points along the continuum are not given proper attention before the industry is developed. A farmer who gets into the soybean business but finds he cannot market his beans, for example, will be less willing to try the next new practice, regardless of its merit or the source of the new idea. A soybean production and food utilization program requires that production, marketing, processing, and utilization of the beans as food be linked together into an over-all program. I am pleased to see that at this conference all facets of such a program are being considered.

One of the reasons soybeans are so exciting is the high nutritional quality of the protein and oil products that can be prepared from soybeans. From a nutritional point of view, soybeans rank high in the protein-quality index (as ascertained by the FAO pattern of essential amino acids).

Soybeans rank below fish, beef muscle, whole milk, and whole eggs, but above sesame seed, cotton seed, peanut flour, and the cereal proteins. If processed properly, soy protein is nearly as good in quality as casein, the major milk protein. In general, soybean protein satisfies the protein requirements of the adult even under limited nitrogen intake. In adolescent and growing youngsters, soybean protein must be supplemented with the sulfur-containing essential amino acid methionine, to achieve adequate nitrogen balance or net nitrogen retention when the total nitrogen intake is limited. However, with relatively large protein intakes, the low methionine content of soy protein is not as important a nutritional factor as at limited protein intakes. In University of Illinois research, rats fed 20 percent protein diets grew at near normal rates and methionine supplementation had only a slight effect on increasing their growth rate. However, at the 10 percent protein level, growth was depressed and methionine caused marked increases in weight gains.

One of the nutritional principles often overlooked is that deficiencies that result from intake of lower quality protein can often be overcome by increasing quantity. Therefore, increasing the availability of any dietary protein can overcome some problems in protein quality.

Cereal proteins, the major protein source for people in many developing countries, are generally of a relatively low quality because they lack adequate amounts of the essential amino acid lysine. However, they contain relatively adequate amounts of methionine, the amino acid lacking in soy protein, and the other sulfur amino acids. Therefore, consuming a mixture of soy protein combined with most any cereal protein results in a well-balanced intake of amino acids equivalent to high-quality protein. And that is one of the reasons why we are excited about prospects for growing soybeans and introducing ways of using them in human diets in developing countries around the world. Combining soybeans and cereals upgrades the nutritional quality of the protein from either source. This reciprocal enhancement can upgrade the nutrition of people who now subsist on protein deficient diets.

But protein content is only one of the factors that make soybeans a potential answer to inadequate nutrition. Soybean oil contains a large percentage of polyunsaturated essential fatty acids and appreciable amounts of carotene. As with any food, soybeans should not be considered as a sole source of nutrition. But when combined with other foods, soybeans--especially as a protein source--can go a long way in upgrading the nutrition of millions of people throughout the world.

In the final analysis, introducing soybeans into human diets depends on organoleptic aspects. Will people accept the taste and texture of soybean-based dishes? We believe that we have overcome many of the problems in this area. The so-called "Illinois process" for preparing whole soybeans results in a product that is relatively bland and can be incorporated into native foods without the characteristic off-flavors usually associated with cooked, whole soybeans. It should also be remembered that the soybean must be cooked before eating to inactivate certain antinutritional factors.

Another problem often associated with human consumption of soybeans is that they result in excessive flatus. The consensus of the researchers at the University of Illinois is that flatus is basically not a problem with soybeans, and that much of the concern is not well founded. For example, navy beans, whey solids, and lactose or sucrose are also very active as flatus inducers. Flatus in soybeans is presumed to be due to the odd sugars--raffinose and stachyose--which are not absorbed and are fermented in the lower intestinal tract.

Many countries have found soybeans to be a productive and adaptable crop and, as I indicated earlier, the purpose of this conference is to review its potential for countries where it is now increasingly evident that the crop has promise and offers reasonable expectations for adaptability to the agri-climatic conditions and for fitting into the cropping patterns.

There is much to be learned about the soybean as a crop before it can be recommended for growing in the tropics and the subtropics. We must recognize there are many problems and there are answers to be found to critical questions about production, technology, plant protection, diseases, insects, and the processing of soybeans. But it is appropriate for the participants of this conference--scientists, agricultural leaders, opinion makers-- to meet for discussions so that they may better understand the issues involved and, on the basis of these discussions, be prepared to make more informed decisions based on knowledge gathered through or by sharing in other people's experiences.

Our responsibility is to set the framework for assembling the very best information possible. And that information must focus on the many elements that must be considered in determining the role soybeans may play in any given country--and for that matter, in all countries looking for a source of high-quality protein and edible oil. And where soy protein and oil can be produced at reasonable cost, we have the exciting opportunity to use those small yellow beans--and all we can learn about them--to benefit the people by improving their natural diets and ultimately their health and well-being.

Soybeans Around the World

C.N. Hittle

Soybeans, *Glycine max* L. Merrill, have been variously referred to as the miracle golden bean, the golden nugget, nuggets of nutrition, pearls of the Orient, the cow of China, the meat of the fields, the meat that grows on vines, the Cinderella crop of the century, the Cinderella crop of the West, the protein hope of the future, and the amazing soybean. Regardless of what they are called, soybeans are a promising and proven source of plant protein and edible oil.

The nutritional value of soybeans has been the subject of many articles (8, 9, 12) and presentations (4) at various conferences and is the topic of some of the speakers at this conference. In the present discussion, it suffices to say that the soybean varieties currently grown in the United States contain 39 to 45 percent (dry matter basis) high quality protein with an amino acid pattern that approaches the optimum Food and Agriculture Organization recommendation. These soybean varieties also contain from 20 to 23 percent (dry matter basis) oil which is quite desirable since it contains considerable unsaturated fatty acids.

Soybeans, together with bananas, barley, common beans, cassavas, coconuts, maize, peanuts, potatoes, rice, sorghum, sugar beets, sugar cane, sweet potatoes, and wheat, are man's principal food plants (5).

ORIGIN AND HISTORY OF THE SOYBEAN

The origin and early history of soybeans are unknown. It is not uncommon to read in agronomic publications that the earliest recorded origins of soybeans date back to 2800 B.C. in China. However, Hymowitz (11) indicates that such statements as "the soybean is one of the oldest of cultivated crops" and "the soybean has been known to man for over 5,000 years" are repeated from one agronomic publication to another without citation or explanation. According to Hymowitz (11), the current evidence for the antiquity of the soybean lies in the pictographical analysis of the archaic Chinese word for soybeans (shu), the Book of Odes, and bronze inscriptions. He concludes that historical and geographical evidence points to the eastern half of North China as the area where the soybean was first domesticated, around the eleventh century B.C. Hymowitz (11) indicates that perhaps Manchuria should be designated as a secondary gene center and the eastern half of North China as the primary center.

Nagata (15, 16) suggests that the cultivated form of soybeans was introduced into Korea from North China and then disseminated to Japan sometime between 200 B.C. and the third century A.D. A second route of dissemination may have been from central China to southern Japan. According to Morse (14), production was more or less localized in China until after the Chinese-Japanese war (1894-1895).

Several references cited by Yule and Burnell (20) suggest that the soybean was known in Europe as an exotic food plant, from the Orient, as early as the seventeenth century. However, it was not until 1712, when Engelbert Kaempfer published his book *Amoenitatum Exoticum*, that the western world fully understood the soybean and its utilization as a food plant (5).

Soybean seed sent from China by missionaries was planted as early as 1740 in the Jardin des Plantes, Paris. According to Aiton (1) the soybean was first brought to England in 1790 and cultivated in the Royal Gardens at Kew. As described in Morse (14) the greatest effort to expand soybean cultivation in Europe was made in 1875 and subsequent years by Frederick Haberlandt of Vienna, who published detailed results of his work. He obtained seed of 19 Chinese and Japanese varieties at the Vienna Exposition in 1873. Four of these varieties matured and seed was distributed to various cooperators throughout Europe.

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Production was not extended, probably because of generally poor climatic conditions. However, shipments of soybeans and soybean products were made to Europe about 1908 and, at that time, the soybean attracted worldwide attention.

The first mention of soybeans in U.S. literature was in 1804 when Mease (13) stated, "The soy-bean bears the climate of Pennsylvania very well. The bean ought, therefore, to be cultivated." Additional information on the introduction of the soybean into the United States is detailed by Probst and Judd (19) and will not be repeated in this presentation.

CURRENT STATUS OF THE SOYBEAN

During the first three decades of the twentieth century soybean production was largely confined to the Orient. China, Indonesia, Japan, and Korea were the major producers of soybeans (6, 17, 18). Soybean production as an important commercial crop in the United States did not begin until the 1930s. However, in the late 1940s and early 1950s, the United States overtook China and eventually the entire Orient in soybean production (19).

As indicated in Table 1, only 168,000 hectares of soybeans were grown for grain in 1925 as compared to 13,951,000 hecatres in 1965 and 22,848,000 hectares in 1973. The principal early use of soybeans in the United States was as a forage crop. They were used mainly for hay, silage, soilage, pasture, and green manure--often in combination with other crops. In 1925 the hectarage of soybeans for hay was three times that grown for beans. It was not until 1941 that the hectarage of soybeans grown for grain first exceeded that grown for forage and other purposes in the United States.

Average grain yields per hectare more than doubled between 1925 and 1973 (Table 1). However, during the past 10 years soybean yields per hectare have not increased in proportion with other crop yields, such as maize and sorghum, and one of the primary objectives of many agronomic and plant breeding programs is to break the "yield barrier" in soybeans.

In Table 2 it is noted that the 1925 soybean production was only 0.3 percent of 1973 production in the United States. Even the 1965 production was only 54 percent of the more than 42.5 million metric tons produced in 1973.

Soybeans in the United States have increased in hectarage by 78 percent from the 1962-1966 average to the 1973 figure of nearly 23 million hectares (Table 3). On a worldwide basis the increase was 56 percent for the same period. During this time the U.S. proportion of soybeans to the world hectarage has increased from 53 to 61 percent. The U.S. production has increased by 104 percent as compared to the world increase of 91 percent for this period (Table 4). Presently the United States produces nearly three-fourths of the world soybean production. The yields per hectare on a world basis are appreciably below U.S. yield levels but the U.S. yields and world yields have increased at about the same rate (Table 5).

Approximately 94 percent of the present production comes from only three countries--the United States, the People's Republic of China, and Brazil (Table 6). Slightly over half (3.2 percent) of the 6.1 percent produced by all other countries is produced by Canada, Mexico, Russia, and Indonesia. Production in Brazil has increased from approximately 146,900 metric tons in 1959 to 4,804,300 metric tons in 1973--a 33-fold increase in 14 years.

In the United States soybeans have ranked first in value of crops sold off the farm for several years. Soybeans and soybean products have been the leading U.S. agricultural exports for dollars since 1962. Approximately 55 percent of the 1971 soybean crop was exported in the form of beans, meal, or oil. The metric tons of soybeans, soybean meal, and soybean oil exported from the United States in the years 1969 to 1972 are indicated in Table 7. The export value of soybeans and products in the United States in comparison with other commodities is indicated in Figure 1. It is noted that well over 3 billion dollars worth of soybeans and products were exported in 1973.

From the review of soybean development in the United States it is seen that little attention was paid to the crop for about 120 years--from 1804 to 1924. Even after soybeans were recognized as a potentially favorable crop, an additional 25 years--from 1924 to about 1949--were required before the industry was really established. Thus, even though soybeans are a relatively new crop in the United States and the growth of the soybean industry is one of the most spectacular in American agricultural history, the industry did not develop overnight.

Table 1. Soybeans grown in the United States for beans and hay, selected years, 1925-1973.

Year	For beans (1,000 ha)	For hay (1,000 ha)	Grain yield (kg/ha)
1925	168	476	787
1935	1,180	1,638	1,130
1945	4,350	786	1,211
1955	7,541	286	1,352
1965	13,951	--	1,648
1970	17,111	--	1,796
1973	22,848	--	1,870

Source: Soybean Digest Blue Book. 1974. American Soybean Assn., P.O. Box 158, Hudson, IA 50643, U.S.A.

Table 2. Soybean production in the United States, selected years, 1925-1973.

Year	Soybeans (1,000 mt)
1925	132
1935	1,332
1945	5,262
1955	10,179
1965	23,034
1970	30,702
1973	42,672

Source: *See* Table 1.

Table 3. Hectares in soybean production, United States and world, selected years.

Year	United States (1,000 ha)	World (1,000 ha)
1962-66 av	12,799	23,988
1971	17,294	30,420
1972	18,508	32,610
1973	22,848	37,539

Source: *See* Table 1.

Table 4. Total soybean production, United States and worldwide, selected years.

Year	United States (1,000 mt)	World (1,000 mt)
1962-66 av	20,939	30,326
1971	32,034	43,731
1972	34,612	47,817
1973	42,672	57,940

Source: *See* Table 1.

Table 5. Average yield of soybeans United States and worldwide, selected years.

Year	United States (kg/ha)	World (kg/ha)
1962-66 av	1,634	1,264
1971	1,850	1,433
1972	1,870	1,466
1973	1,870	1,540

Source: See Table 1.

Table 6. World soybean production, 1973.

Country	Percentage of total
United States	74.0
People's Republic of China	11.6
Brazil	8.3
All other	6.1

Source: See Table 1.

Table 7. U.S. Soybean Exports, 1969-1972.

Year	Whole soybeans (1,000 mt)	Soybean meal (1,000 mt)	Soybean oil (1,000 mt)
1969	11,784	3,661	645
1970	11,817	4,136	791
1971	11,354	3,452	635
1972	13,079	4,305	485

Source: See Table 1.

Table 8. U.S. Department of Agriculture germ plasm collection of soybeans.

Classification of germ plasm	Number
U.S. and Canadian varieties	300+
Forage Crop strains	91
Plant Introduction strains	3000+
Genetic types	91
Species	152
	3600+

Source: R.L. Bernard, U.S. Regional Soybean Laboratory, Urbana, IL, 61801, U.S.A.

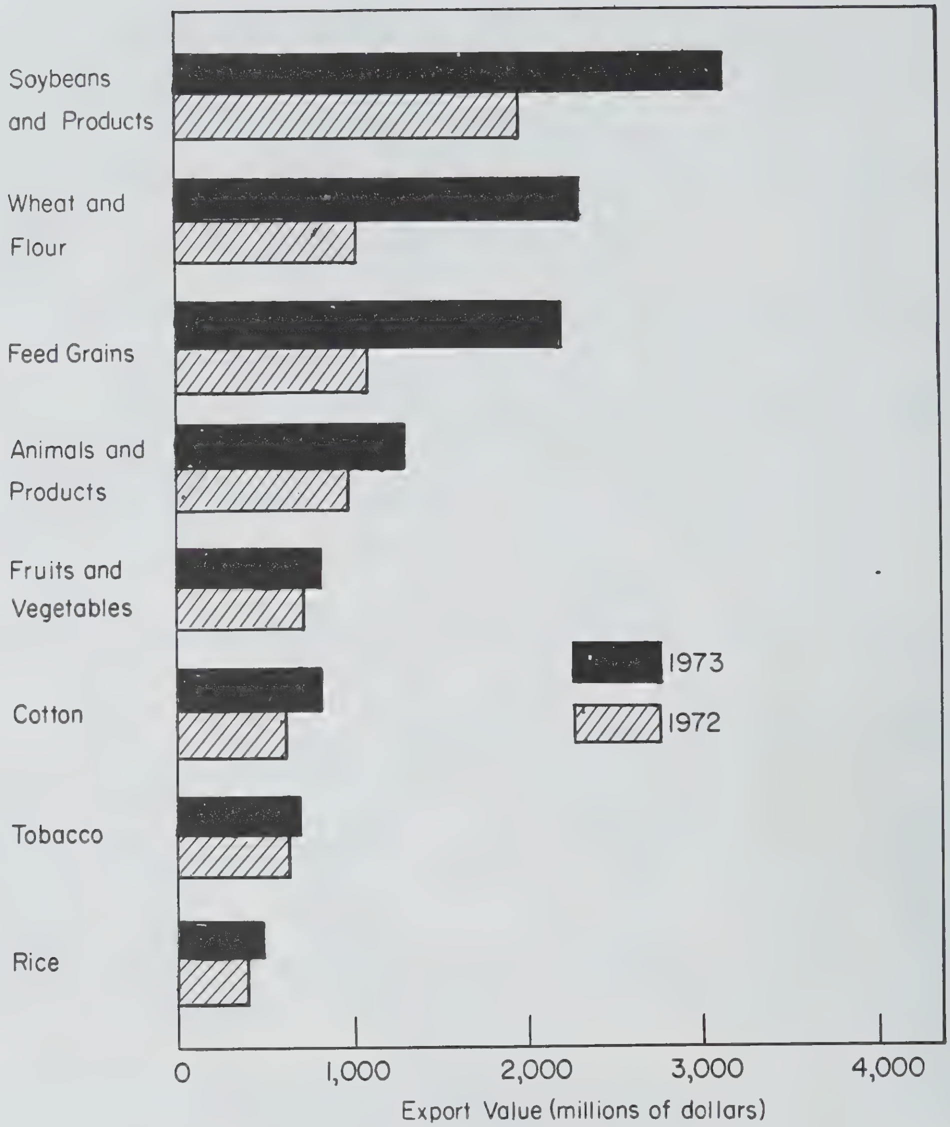

Fig. 1. Export value of soybeans and soybean products in the United States, 1972 and 1973.

SOYBEAN PRODUCTION RESEARCH IN THE UNITED STATES

In discussing the rise to prominence of soybeans in the United States and other countries, it would be inappropriate to omit mention of the soybean production research that has been conducted for at least the past 50 years. Improved, adapted, high-yielding varieties with resistance to insects, diseases, nematodes, seed shattering and lodging; better cultural methods, including effective herbicides; increased fertility; and improved machinery have been important factors in the increase in average U.S. yields from 740 kg/ha (11 bu/acre) in 1924 to an all-time high of 1,870 kg/ha (27.8 bu/acre) in 1972 and 1973.

Extensive reviews of soybean production research are covered in Soybeans: Improvement, Production and Uses, which has already been cited (7). An excellent summary of the history of soybean research at the University of Illinois was presented at the International Soybean Program (INTSOY) steering committee meeting on July 9-10, 1973, by R. W. Howell (10). Therefore only a few of the research accomplishments will be highlighted in this discussion.

Soybean production research is being conducted by several units at many experiment stations and research centers. At the University of Illinois these units include the U. S. Regional Soybean Laboratory and the departments of agronomy, botany, agricultural engineering, and agricultural economics. For many of the studies there is inter- and intra-departmental cooperation, including the close working associations of the college of agriculture and the U. S. Regional Soybean Laboratory.

Because of their response to photoperiod, most soybean varieties are adapted for full-season growth in a band usually no wider than 100 to 150 miles from north to south. Until recently, the Canadian and U.S. researchers divided soybean varieties into 10 maturity groups, from 00 (earliest maturing) through VIII. Two additional groups have now been added, IX and X, which include newly developed subtropical varieties. For example, the variety Jupiter, developed at the University of Florida, does well in Guyana and Puerto Rico and is in maturity group IX. The range in maturity within a group varies from 10 to 18 days. As D. K. Whigham indicates in his presentation, maturity groups must be reassigned when U.S. varieties are moved to new environments.

The break-down of the world germ plasm soybean collection is shown in Table 8. The collection is maintained, evaluated, and disbursed by the U. S. Department of Agriculture Regional Soybean Laboratory at Urbana, Illinois, and Stoneville, Mississippi. It consists of varieties, introductions that came in as forage crop accessions, Plant Introduction numbers, genetic types, and 151 introductions of species other than *Glycine max*.

Recently the University of Illinois Department of Agronomy has developed a computerized germ plasm information system in which all information from the more than 3,600 lines and varieties is recorded. The system is set up to accommodate 140 different characteristics of each strain. This information will be made available to soybean research personnel throughout the world.

In addition to the USDA germ plasm collection, the Asian Vegetable Research and Development Center in Taiwan had (by the end of 1973) 3,064 soybean accessions (2). Undoubtedly some of these accessions are duplicates of the USDA accessions.

The following examples demonstrate the progress resulting from the various genetic, breeding, and crop production programs at the University of Illinois, the U. S. Regional Soybean Laboratory, and other experiment stations and research centers.

1. Within the past 15 to 20 years, *Phytopthora* root rot has been discovered and has been quite severe. Researchers identified the causal organism, worked out the inheritance, and employed a backcross program to incorporate resistance into many existing and new varieties.

2. In recent years the cyst nematode has threatened soybean production in the Southern States and southern portion of the Northern States. Resistance has been identified and incorporated into new varieties. The so-called Peking resistance is controlled by four major genes.

3. Most soybean introductions are susceptible to lodging and, within the past 30 years, plant breeders have been highly successful in breeding for resistance to this characteristic. However, further improvement of many lines is still needed. Many high-yielding soybean varieties grown under very high fertility and favorable environmental conditions frequently lodge.

4. Soybeans are commonly grown in rows 90 to 105 cm apart. Recent research findings indicate that, under many situations, this row width is too wide for optimum yield and weed control. At 45 cm row spacing there is complete filling-in between rows, frequently resulting in higher yield and more effective weed control.

5. Soybean varieties grown in the Northern States are indeterminate while those grown in the Southern States are determinate (or semidwarf). Researchers are taking a hard look at growth habit, especially in relation to lodging, to determine which type will consistently produce maximum yields at given latitudes.

6. The sugars raffinose and stachyose have been implicated as causative factors for the flatulence and uncomfortable feeling often experienced after consuming products containing soybean meal. The value of soybeans might be enhanced if the oil and protein content remained high and the raffinose and stachyose content were lowered to make them more acceptable for human consumption. Screening of selected lines for raffinose and stachyose indicates considerable range in values, suggesting that selection would be effective for decreased sugar content.

7. Unheated soybean meal is inferior in nutritional quality to properly heated meal. Trypsin inhibitor in raw soybeans has been proposed as one of the factors responsible for the poor nutritional value of unheated meal. Recently a genetically controlled variant (or mutant) of soybean trypsin inhibitor (SBTI) has been found. The most commonly occurring SBTI (Ti^1) produces a fast electrophoretic band at Rf .79. (Rf = mobility relative to the dye front.) The variant (Ti^2) produces a slow-moving band at Rf .75. The hybrid between the two genotypes produces both bands. The results confirm that a single locus with two codominant alleles controls the two protein forms and that genetic variability exists for SBTI.

8. Soybean chromosomes are very small, and good pollen mother cell and root tip preparations require considerable skill. The normal diploid (2n) number of *Glycine max* L. is 40. However, 41 chromosome types (trisomics) have been produced and identified through cytological studies. Trisomics, or extra chromosomal types, are useful in analyzing the inheritance of important characters.

9. Soybean breeders are interested in male sterile types, not only in studying the feasibility of hybrid soybeans but also for the production of hybrid populations in a breeding program. Hand pollination is tedious and the number of crosses obtained is frequently limited. In recent years soybean breeders have isolated male sterile lines. At the University of Illinois, researchers have produced male sterile genotypes through interspecific hybridization.

THE INDIA STORY

From 1965 to 1973, several University of Illinois scientists were associated with the soybean development program in India, which was part of the University Development Program. The Coordinated Research Project on Soybeans, in every sense, emphasized the team approach. To begin with it was a joint venture of the Indian Council of Agricultural Research (ICAR), G. B. Pant University of Agriculture and Technology (Pantnagar, U.P., India), Jawaharlal Nehru Agricultural University (Jabalpur, M.P., India), U.S. Agency for International Development (USAID), and the University of Illinois, with assistance from the Ministry of Agriculture, Government of India. More recently the departments of agriculture in the states of India, many additional universities, and various other organizations have entered into this cooperative program. Coordination of research, teaching, and extension have been and are considered essential in order for the project to have an impact on Indian agriculture.

This project has also provided a working model for coordinated intra- and inter-institutional research. Plant breeders, agronomists, botanists, pathologists, entomologists, microbiologists, agricultural engineers, agricultural economists, and extension workers are concerned with producing the crop and getting it to the consumer. Efforts by food technologists, food processors, industrial engineers, and home economists are directed at ensuring that soybeans and soybean products will find a place in the Indian diet.

The results of the Indian program have been very encouraging. The performance of a few of the soybean varieties evaluated in experimental plots in central India is shown in Table 9. The better-performing varieties are those from the Gulf Coastal States of the U.S., i.e. the southern varieties.

In 1971 many on-farm demonstration plantings were grown throughout the state of Madhya Pradesh. Each planting was one acre in size. As indicated in Table 10, yields from 42 of the plantings varied from 1,000 to 3,800 kg/ha (15 to 57 bu/a). Thus the better yields obtained from demonstration plantings were comparable to those obtained at the research center. The results indicate the yield potential, for the cultivator, when strict attention is paid to all steps of the "Package of practices."

Table 9. Performance of several soybean varieties evaluated during the monsoon seasons at J. Nehru Agricultural University, Jabalpur, India.

Variety[a]	Maturity group	Yield: 4 yr av 1968-71 (kg/ha)	Yield: 5 yr av 1967-71 (kg/ha)
Bragg	VII	3,310	3,160
Semmes	VII	3,170	--
Davis	VI	3,150	--
Lee	VI	2,950	2,870
Hood	VI	2,800	2,740
Pb-1	--	2,790	--
Clark 63	IV	2,200	2,210

a/ All varieties are introductions from United States except Pb-1 which is an Indian selection.

Table 10. Yields obtained from 42 demonstration plantings throughout Madhya Pradesh state, India, 1971.

District	Number of Plantings	Yield: Range (kg/ha)	Yield: Average (kg/ha)
Seoni	14	1,180-3,800	2,420
Sehore	18	990-2,670	2,080
Indore	10	1,560-1,950	1,750

Table 11. Soybean grain yields (Bragg variety) as influenced by inoculation and nitrogen applications, J. Nehru Agricultural University, Jabalpur, India.

Nitrogen fertilizer (kg/ha)	Two-year averages, 1968-69: Inoculated[a] (kg/ha)	Two-year averages, 1968-69: Not inoculated (kg/ha)
0	3,640	2,010
30	3,680	2,300
120	3,740	2,700

a/ Inoculated with N inoculum from United States

Table 12. Response of Bragg soybeans to inoculation without nitrogen fertilization, Jabalpur, India.

Treatment	Yield: 1968 (kg/ha)	Yield: 1969 (kg/ha)
Control (uninoculated)	1,860	1,800
Nitragin[a]	3,750	3,600

a/ Inoculum from United States.

In central India yields of plots inoculated with *Rhizobium japonicum* bacteria have been higher than those of uninoculated plots even with the addition of 120 kg/ha (108 lb/a) of nitrogen fertilizer (Table 11). As shown in Table 12, yields have been doubled by ensuring effective inoculation and nodulation. When soybeans are introduced into new areas it is of vital importance to also introduce highly effective strains of *R. japonicum*.

INTSOY--THE INTERNATIONAL SOYBEAN PROGRAM

What is INTSOY? The International Soybean Program (INTSOY) is a cooperative program between the College of Agriculture of the University of Illinois at Urbana-Champaign and the University of Puerto Rico, College of Agricultural Sciences, Mayaguez.

INTSOY was formally established in 1973, but its organizational roots are planted in the long-standing international interests and activities of several institutions. The University of Illinois has long been interested in soybean research and development both domestically and internationally. Through cooperation with other agencies--particularly the U.S. Department of Agriculture--Illinois has developed extensive programs. At the same time, the University of Puerto Rico has had a long-term interest in food legumes and more recently has focused attention on soybeans. The institution also contributes a high level of expertise in tropical and subtropical agriculture.

INTSOY is concerned with all phases of soybean production and use from planting the seed to consumption. These phases include production, harvesting, marketing, processing, and utilization. INTSOY's major interest is in the exploitation of the remarkable potential of soybeans as a source of protein for direct human consumption. Research focuses primarily on the problems of tropical and subtropical environments but is also concerned with nutrition and processing as ways to expand use of soybean protein foods in human diets.

The INTSOY program is developing cooperative work with, and through support from, the U.S. Agency for International Development, international research centers, foundations, universities, and other agencies. Outreach activities, including assistance with research, extension, and long-range agricultural development, have been initiated with several countries. Currently, USAID and the Rockefeller Foundation provide most of the financial support, but a broadened base of support is needed to attain the full potential that rests in INTSOY.

The first issue of the INTSOY Newsletter was published and distributed in August 1974. Future issues will be published every two or three months.

The INTSOY component at the University of Illinois has recently added a plant pathologist, an entomologist, and a plant breeder to its staff. The plant breeder is stationed at the University of Puerto Rico, Mayaguez Campus, and is initiating a tropical soybean breeding program. The pathologist and entomologist are stationed at Urbana, Illinois.

The INTSOY component at the University of Puerto Rico has recently added a plant pathologist and a physiologist (weed control specialist) to its staff. Both scientists will be stationed at Mayaguez.

Commencing in 1975, INTSOY will be conducting two training programs, one on "Technical and Economic Aspects of Soybean Production" (18 weeks) and the other on "Soybean Processing for Food Uses" (6 weeks).

SUMMARY

We are all most fortunate to be able to attend and participate in a conference such as this, and to attempt to fulfill the four major objectives that were so well delineated by your conference program committee. We are here to exchange information and ideas, to present results of research and demonstration trials, to set up procedures for the orderly exchange of germ plasm. But most of all we are here to become acquainted with one another on a person-to-person basis, to provide closer ties with the various programs--in order that our mutual problems can be attacked through coordinated approaches and efforts.

The success of this conference not only will be measured by the fulfillment of the objectives, as outlined, but will depend upon what each of us does after we return to our own programs. The development and success of a soybean industry does not just happen. It requires an organized program, managerial skills, the continuing efforts of all people concerned, a sense of urgency, a high degree of competence, and a keen appreciation and application of the lessons that have been learned by others.

When soybeans are introduced into any area or country for the first time, it is much easier to prove that soybeans cannot be grown than it is to prove that they can be grown successfully. Even though the soybean originated from a temperate climate, it has been a secondary crop in Southeast Asia for many years and has done very well under rather adverse conditions in that part of the world. Recent results from carefully conducted experimental trials in Africa, the Middle East, and South Asia, as well as Mesoamerica and South America, suggest considerable scope for the soybeans in at least some of these countries.

Soybeans are a fascinating and an amazing crop. To find their rightful place in this part of the world requires the continued efforts, cooperation, and skills of individuals such as you who are participants of this conference.

REFERENCES

1. Aiton, W.T. 1814. Page 226 in W.T. Aiton, Epitome of hortus kewensis. 2nd ed. Richard and Arthur Taylor, London.

2. Anonymous. 1974. Annual Report 1972-73. Asian Vegetable Research and Development Center, Taiwan.

3. Bening, W. 1951. First published report on soybeans. Soybean Dig. 11(3):20-22.

4. Bentley, O.G. 1966. Soybean production in the world--limitations and potentials. In Proceedings, international conference on soybean protein foods, Peoria, Ill., October 1966. U.S. Dept. Agr., ARS-71-35.

5. Brooks, H. 1966. Applied and economic botany. In Natl. Acad. of Sci., The plant sciences now and in the coming decade. Natl. Res. Council Pub. 1405, pp. 100-114.

6. Burtis, E.L. 1950. World soybean production and trade. Pages 61-108 in Soybeans and soybean products, Vol. 1. K. S. Markely, ed. Interscience Publishers, Inc., New York.

7. Caldwell, B.D. 1973. Soybeans: improvement, production and uses. Agronomy Series No. 16. American Society of Agronomy, Madison, Wis.

8. Chen, P.S. 1956. Soybeans, for health, longevity and economy. Chemical elements, South Lancaster, Mass.

9. Dies, E.J. 1942. Soybeans, gold from the soil. Macmillan, New York.

10. Howell, R.W. 1973. A history of soybean research at Illinois. Pages 1-8 in Proceedings, INTSOY Steering Committee. University of Illinois, Urbana.

11. Hymowitz, T. 1970. On the domestication of the soybean. Econ. Bot. 24:(4)408-421.

12. Lager, J. 1945. The useful soybean. McGraw-Hill, New York.

13. Mease, J. 1804. Page 13 in Willich's domestic encyclopedia. Vol. 5. 1st Amer. ed. Philadelphia.

14. Morse, W.J. 1950. History of soybean production. Pages 3-59 in Soybeans and soybean products, Vol. 1. K. S. Markley, ed. Interscience Publishers, Inc., New York.

15. Nagata, T. 1959. Studies on the differentiation of soybeans in the world with special regard to that of Southeast Asia. Proc. Crop Sci. Soc. Japan 28:79-82.

16. Nagata, T. 1960. Studies on the differentiation of soybeans in Japan and the world. Men. Hyogo Univ. Agr. 3(2) Ser. 4:63-102.

17. Piper, C.V., and W.J. Morse. 1910. The soybean: history, varieties, and field studies. U.S. Dept. Agr. Bur. Plant Ind. Bull. 197 pp. 1-84.

18. Piper, C.V., and W.J. Morse. 1923. The soybean. McGraw-Hill, New York.

19. Probst, A.H., and R.W. Judd. 1973. Origin, U.S. history and development and world distribution. Pages 1-15 in Soybeans: improvement, production and uses. B.E. Caldwell, ed. Agronomy Series No. 16. American Society of Agronomy, Madison, Wis.

20. Yule, H.C., and A.C. Burnell. 1903(reprinted 1968). Hobson-jobson. Humanities Press, New York.

DISCUSSION

L.K. OPEKE: What are the possibilities of extending the INTSOY program to other parts of the world, especially Africa?

C.N. HITTLE: The possibilities are excellent. INTSOY is attempting to establish strong linkages with existing international centers. They are also desirous of establishing sub-centers at various locations, perhaps on a regional basis.

INTSOY has had, since April 1973, a Basic Ordering Agreement with USAID--i.e., an outreach program. This BOA provides a mechanism whereby countries can make requests for technical services and, if INTSOY can respond to the request, a Task Order is issued which covers the details of the contract.

We are receptive to any suggestions relative to mechanisms and procedures that may be developed to effectively assist various countries, regions, and areas with a soybean development program.

A. ASSA: In breeding programs, does the plant breeder breed for plant height?

HITTLE: Yes, breeding for plant height is important in terms of lodging and mechanical harvesting.

The lowest pod can be selected in two ways: (1) selection for height of the lowest pod, and (2) selection for the total height of the plant. When U.S. varieties are moved to lower latitudes, frequently the soybean plant flowers very early (in response to a shorter day length) resulting in a very short plant with the lowest pod-bearing node too low for machine (combine) harvesting. An objective of tropical breeding programs will probably be the breeding for selection of increased height of the lowest pod-bearing node.

D.W. JOHNSON: I assume the figures given for range of analysis for oil and protein in beans was on a dry basis?

HITTLE: Yes, the figures are on a dry matter basis. This should have been emphasized in the presentation.

S.D. AGBOOLA: Our experience in Nigeria (Ibadan) has been a lack of response to inoculation from some imported *Rhizobium* strains from the United States. In addition to other possible factors, we think it might be an indication of inadequate competitive ability of the imported strains with indigenous rhizobia. We are thinking of looking for local strains which might prove better. What are your views on this?

HITTLE: One of the factors that concerns INTSOY most is to attempt to introduce the most highly effective rhizobial strains at the same time that soybeans are introduced into a new area. My experience in India, Sri Lanka, and the United States, and reports from many other countries, indicates that at least some U.S. inoculums are highly effective. However, if response to inoculum is not good, research should be conducted to determine the reason(s) for lack of response. It may be that method(s) of inoculation are not adequate or that bacteria are being killed by high temperature before seed is covered with soil. Also, of course, it may be that the introduced strains are not competitive.

M.Z. JOWANA: What about the date of sowing? And what is the length of maturity?

HITTLE: In central India, sowing is usually most successful when made at beginning of monsoon, from about June 15 to July 1. At Jabalpur, India (23° N latitude) maturity usually was from about 90 to 120 days. Bragg variety matured in 110 days.

T.I. ASHAYE: The farmers' yield in India was quoted as about two-thirds of the yield under experimental conditions. Were these yields obtained by employing the extension workers of the Ministry of Agriculture or did you actually lay out the work and supervise it yourself with your staff?

HITTLE: The trials referred to were one-acre on-farm demonstration trials. Farmers were selected by the extension specialist (village-level worker) and were supervised by the district agricultural officer and the VLW. The extension and research personnel of the agricultural university worked closely with Ministry of Agriculture personnel in providing training for the ministry personnel who, in turn, did most of the guidance and follow-up of the demonstration plantings. Special efforts were made to encourage the selected farmers to follow the recommended "package of practices."

W.J. KAISER: Has it been your experience in India and elsewhere that when the soybean acreage was increased, certain diseases and pests became important factors in production of the crop?

HITTLE: Yes, not too long after soybeans were grown in North India on an appreciable hectarage, two diseases threatened the crop--virus yellows and rust. Neither of these diseases is present in Illinois. Much of the world germ plasm collection of soybeans was sent to Pantnagar, India, where it was screened for both virus yellows and rust. Resistance was discovered and is now being incorporated into local high-yielding varieties.

E.V. DOKU: How would you rank flower, pod, and grain abortions as sources of yield erosion? How far would you attribute this to the genotype environment or both factors?

HITTLE: Usually a large percentage of the flowers abort and many researchers have used various treatments to increase flower retention, but without success. This apparently takes place under most, if not all, environments. To my knowledge excessive "flower drop" has not been attributed to specific genotypes. The questioner is referred to the information on pages 66-67 of Soybeans: Improvement, Production and Uses (7).

W. PLARRE: I think the inoculant Nitragin is a population of different strains; are you informed about the components of most strains?

HITTLE: Nitragin brand inoculum is a composite of several strains, as are most if not all, U.S. inoculums. I believe that most, if not all, inoculums manufactured in Australia are single-strain cultures.

Soybean Variety Evaluation

D.K. Whigham

Environmental influence on soybean (*Glycine max* L. Merr.) plant and seed characteristics have been reported (1-14). All locations have a slightly different environment which varies between seasons. Cultivars respond differently to changes in the environment. Therefore, prediction of varietal adaptation on a worldwide basis becomes very difficult.

Standardized soybean variety evaluation experiments were tested in several countries during 1973, as a part of a research program being carried out for the United States Agency for International Development (AID). These trials were organized to determine if soybeans will grow in different areas of the world, what varieties or types are best adapted, and what is the potential of soybeans in the different environments. Variety testing is the first step of a breeding program to develop varieties better adapted to tropical areas. The International Soybean Program (INTSOY) at the University of Illinois and the University of Puerto Rico is attempting to improve soybean production and utilization in the tropics and subtropics.

MATERIALS AND METHODS

Germ plasm used in these trials are varieties from various areas of the United States which have a high yield potential in a given environment. Twenty varieties from maturity gropus I to IX were tested (Table 1). The trials were designed by INTSOY staff and instructions for management and data collection were prepared and sent to the cooperator with the seed and inoculant. Each variety was replicated four times in a randomized complete block design. Plots included four 60 cm rows 6 meters long. Five meters of the two center rows were harvested. Eleven plant and seed variables were measured. Seed samples of each variety were analyzed for protein and oil content. Upon completion of the trial, the data were sent to INTSOY for computer analysis. A copy of the results was returned to the cooperator for local use.

Cooperators were competent scientists with experience in experimental research. They included Ministry of Agriculture, university, and research institute staff.

Table 1. Varieties and U.S. maturity group designation for the 1973 soybean variety evaluation experiment.

Variety	Maturity group
Jupiter	IX
Hampton 266A	VIII
Hardee	VIII
Hutton	VIII
Improved Pelican	VIII
Bragg	VII
Semmes	VII
Davis	VI
Lee	VI
Pickett 71	VI
Dare	V
Hill	V
Bonus	IV
Clark 63	IV
Cutler 71	IV
Adelphia	III
Calland	III
Williams	III
Harosoy 63	II
Hark	I

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RESULTS AND DISCUSSION

Results from 36 of the test sites in 16 countries (Fig. 1) have been summarized. The environmental conditions of each location differ greatly. Table 2 indicates the variation in altitude and latitude of the test sites.

A survey of the highest-yielding variety at each location shows the variation in plant and seed characteristics at the 36 locations (Table 3). A mean yield of 2,388 kg/ha indicates that there is a potential for soybean production in most of these countries. Seed weight varied more than threefold at the different locations. The range in days to maturity represents a short season variety and a moderately long season variety as determined by the genotype x environment interaction. Plant height varied by more than fourfold at different sites.

The most consistent high-yielding varieties were determined by scoring the variety that produced the top yield at a given location, or one which produced a yield not significantly different, at the 5 percent level, from the top yield at that location. The most consistent varieties were Hardee, Williams, Davis, Hampton 266A, Pickett 71, Lee 68, Clark 63, and Improved Pelican; in that order (Table 4). Varieties from several different U.S. maturity groups were represented by consistently high yields. However, the varieties seldom matured in the same number of days or in the sequence of the groups to which they were assigned in the United States.

Several countries have reported results from more than one location. The mean top yield across locations is presented in Table 5. All countries except Thailand show yields of 2 t/ha or more. Ecuador and the Philippines indicate a potential of more than 3 t/ha.

The most consistent varieties (Hardee, Williams, and Davis) have been examined to determine their response to environmental differences. Table 6 shows the effect of seed weight, days to maturity, plant height, latitude, and altitude on yield. Grain yield increased as seed weight increased, with the exception of seed weight greater than 25 g in Hardee and Williams, and less than 10 g in Hardee, where only one sample was reported. Davis produced no 100-seed weights greater than 25 g. The highest frequency of locations occurred in the range of 16 to 20 g for Williams and Davis. Hardee seed weighed between 10 to 15 g most often. Results were not received for each variety or variable from all 36 locations.

Grain yield increased as the number of days to maturity increased with Hardee and Davis. Williams did not follow the same trend because of low yields within the range of 101 and 120 days. All varieties had the highest frequency of locations maturity between 80 and 100 days.

Hardee is the exception to increased yield as plant height increased. Taller plants better utilize available light and may have greater photosynthetic area. Plant heights from 30 to 60 cm were most common for all varieties. Davis was less than 30 cm tall at more locations than the other varieties and produced no plants taller than 90 cm at any location. Williams was reported to have plant heights greater than 60 cm at the greatest number locations. Williams has an indeterminate growth habit, whereas Hardee and Davis are determinate.

Yield decreased as latitude increased up to 20^{o}. A few high-yielding locations at more than 20^{o} latitude resulted in higher mean yields than at latitudes from 10^{o} to 20^{o}. More trials were located between 5^{o} and 10^{o} than at any other latitude range. On June 22 at 20^{o} N the day length is approximately 1.25 hr longer than at the equator (15). On December 22 the day length is approximately 1.2 hr shorter at 20^{o} N than at the equator. However, day length does not change at the equator where there are approximately 12.5 hr of light daily.

As altitude increased, the yield response of each variety was inconsistent. However, the pattern of response was similar for all three varieties. Each variety produced its highest yield in the range of 1,000 to 1,500m. None of the reporting locations were between 500 and 1,000m in altitude. Most of the sites were located at less than 500m.

Table 6 also shows the response in plant height to seed weight, days to maturity, latitude, and altitude for varieties Hardee, Williams, and Davis. Little difference was noted when comparing seed weight to plant height except at the extremes in seed size.

Plant height responded positively to increased days to maturity, except for Williams between 101 and 120 days. A longer season permitted taller growth of the plants. Hardee grew considerably taller than the other varieties when the days to maturity were greater than 120. When maturity occurred within 120 days, Williams was the tallest variety.

Mesoamerica
Puerto Rico

South America
Colombia
Ecuador

Africa
Egypt
Ethiopia
Ghana
Sierra Leone

Asia
Afghanistan
India
Indonesia
Malaysia
Pakistan
Philippines
Sri Lanka
Thailand
Vietnam

Fig. 1. Countries from which data were collected in soybean variety evaluation experiments in 1973.

Table 2. The range and mean in altitude and latitude of the 36 locations represented in this study.

	Range	Mean
Altitude	21 m to 1,803 m	507 m
Latitude	7^{o} S to 34^{o} N	14^{o}

Table 3. The range and mean in grain yield, 100-seed weight, days to maturity, and plant height of the highest-yielding soybean variety at the 36 locations represented in this study.

	Range	Mean
Grain yield (kg/ha)	280.9 to 4826.4	2,388
100-seed weight (g)	7.4 to 23.8	17.5
Days to maturity	62.3 to 149.0	100.5
Plant height (cm)	22.0 to 93.0	51.0

Table 4. Soybean varieties, maturity group, and percentage of locations where the variety produced the highest yield or a yield not significantly different (5 percent level) from the highest yield.

Variety and maturity group	Percentage of locations
Hardee (VIII)	53
Williams (III)	44
Davis (VI)	42
Hampton 266A (VIII)	36
Pickett 71 (VI)	36
Lee 68 (VI)	33
Clark 63 (IV)	31
Improved Pelican (VIII)	31

Table 5. Number of locations and mean grain yield of soybeans for those countries with multiple locations.

Country	Number of locations	Mean grain yield (kg/ha)
Ecuador	3	3,310
Indonesia	2	1,992
Philippines	2	3,405
Puerto Rico	4	2,610
Sri Lanka	9	2,662
Thailand	6	1,385

Table 6. Mean grain yield and plant height of soybean varieties Hardee, Williams, and Davis with different seed weights, days to maturity, plant height, latitude, and altitude.

	Grain yield (kg/ha)			Plant height (cm)		
	Hardee	Williams	Davis	Hardee	Williams	Davis
100-seed weight (g)						
<10	1,878(1)[a]	169(1)	552(2)	34.5	28.5	49.7
10-15	1,464(13)	1,009(7)	1,238(11)	42.3	47.8	39.6
16-20	2,349(10)	1,897(16)	2,077(15)	43.3	46.4	36.7
21-25	3,579(3)	2,504(9)	3,103(5)	41.9	51.9	37.3
>25	2,842(1)	2,279(1)	--	30.5	44.5	--
Days to maturity						
<80	871(2)	722(2)	527(2)	24.7	39.4	29.8
80-100	2,059(14)	2,083(24)	1,906(17)	35.0	48.4	33.6
101-120	2,237(9)	1,297(5)	2,132(10)	43.0	46.1	42.2
>120	2,501(3)	2.169(2)	2,472(3)	83.2	56.6	52.3
Plant height (cm)						
<30	1,377(8)	707(7)	827(10)			
30-60	2,412(18)	1,793(21)	2,283(21)			
61-90	1,745(2)	2,649(7)	2,409(4)			
>90	2,742(1)	3,026(1)	--			
Latitude of location (degrees)						
<5	2,619(5)	2,410(5)	2,799(5)	32.0	45.9	34.8
5-10	2,001(13)	2,013(15)	1,970(15)	38.8	44.8	34.6
11-15	2.123(3)	1,327(4)	1,487(4)	40.0	50.6	32.4
16-20	1,542(7)	1,319(8)	1,297(8)	44.9	42.9	41.6
>20	2,243(2)	1,966(4)	1,994(3)	75.8	63.4	58.6
Altitude of location (meters)						
<100	2,049(13)	1,897(15)	1,883(15)	40.1	52.4	40.2
100-500	1,827(13)	1,621(16)	1,632(16)	34.8	38.6	66.4
1000-1500	2,222(3)	2,349(3)	3,025(3)	56.1	48.3	45.7
>1500	1,794(1)	2,271(2)	2,416(1)	66.5	70.8	55.5

[a] Numbers in parentheses - number of locations per mean value.

A trend of increased plant height with increased altitude was shown at altitudes above 100 m with Hardee and Williams. Davis followed the same trend with the exception of the 100 to 500 m range which resulted in the tallest plants for that variety. Williams produced the tallest plants at altitudes greater than 1,500.

Table 7 shows latitude and altitude as influenced by seed weight and days to maturity. The interaction between seed weight and days to maturity is also shown. Seed weight in the range of 10 to 15 g was produced at the highest mean latitude for varieties Hardee and Williams. The highest mean latitude resulted in the smallest seed weight for Davis. Latitudes nearest the equator reported the largest seed weight for all three varieties.

Days to maturity increased as latitude increased with each variety. Plants took longer to complete their life cycle during the longer day length environments. The longer days permitted more plant development before flowering and maturity occurred, but did not have a positive yield response.

Seed weight in the range of 16 to 20 g was produced at the highest mean altitude with Hardee and Davis. The 10 to 15 g range seed weight was produced by Williams at the highest altitudes. Each variety produced its largest seed at the lowest altitude. However, Hardee produced seed weighing over 25 g/100 seeds at 17 and Williams produced the same-size seed at the mean altitude of 138 m.

Table 7. The effect of latitude and altitude on seed weight and days to maturity and the effect of days to maturity on seed weight of varieties Hardee, Williams, and Davis.

	Latitude (degrees)			Altitude (meters)			100-seed weight (g)		
	Hardee	Williams	Davis	Hardee	Williams	Davis	Hardee	Williams	Davis
100-seed weight (g)									
<10	6.0	13.0	24.5	75	500	168			
10-15	16.6	21.6	13.1	224	404	258			
16-20	9.4	12.4	12.9	456	288	349			
21-25	3.0	7.9	3.8	191	326	146			
>25	2.0	8.0	--	17	138	--			
Days to maturity									
<80	6.5	7.0	5.0	20	30	30	12.9	15.9	12.9
80-100	9.6	10.9	9.8	248	233	290	15.2	18.8	16.4
101-120	14.3	19.0	14.2	266	737	230	17.0	18.4	17.8
>120	20.5	20.5	19.7	1,425	1,210	960	15.4	18.5	17.3

Days to maturity increased with an increase in altitude with one exception at the 101 to 120 day range for Davis. An increase in altitude normally results in a decrease in temperature, especially at night. Therefore, altitude resulted in delayed maturity as did latitude. Therefore, both day length and temperature interact to delay maturity. However, altitude had a more positive effect on yield than did latitude (Table 6).

Seed weight increased as days to maturity increased up to 120 days maturity with varieties Hardee and Davis. Williams seed weight only changed slightly when maturity took more than 80 days.

Maximum yield was attained with all varieties when days to maturity were greater than 120 (Table 6), but seed weight was not at a maximum in that range. Therefore, seed number is the yield component which gave the yield advantage to the highest maturity range. Seed number was not measured in this experiment. Maximum plant height was attained during the maximum range in maturity for all varieties, and maximum yield was achieved with the tallest plant height range (Table 6). Assuming that taller plants result in more vegetative growth, the plants are capable of supporting more seeds during the reproductive stage. Therefore, more flowers were initiated or fewer were aborted when the plants were tall.

Protein and oil analysis results are summarized in Table 8. All samples were analyzed on the same grain analyzer (11) at the University of Illinois, Department of Agronomy. The highest protein reported was 51 percent with an oil content of 22.2 percent from the same sample. The lowest oil content was 17.9 percent. Both high protein and low oil samples came from the same trial in Mayaguez, Puerto Rico, but from different varieties. The lowest protein (30.5 percent) was reported from Mexico as was the highest oil (31.5 percent).

Each variety was also examined to determine the mean protein and oil content across all locations. Hutton variety had the highest protein content (43.3 percent) and Hill had the lowest (37.9 percent). The highest oil content was observed in variety Dare (25.1 percent) and the lowest oil content was in Hill (22.2 percent). The average content across all varieties and locations was 40.6 percent protein and 21.9 percent oil. The variation in protein and oil content can be attributed to the variation in soil fertility, fertilizer and inoculum applications and crop management among the different locations.

Table 8. The range and mean in protein and oil content across locations and varieties.

	Protein percent	Oil percent	Variety
Range			
Locations			
High protein	51.0	22.2	Pickett 71
Low protein	30.5	29.2	Hill
High oil	32.9	31.5	Bonus
Low oil	41.0	17.9	Davis
Variety mean			
High protein	43.3	23.0	Hutton
Low protein	37.9	22.2	Hill
High oil	40.4	25.1	Dare
Low oil	37.9	22.2	Hill
Mean			
Across varieties (20) and locations (35)			
	40.6	21.9	

In summary:

1. Maturity groups must be reassigned when varieties are moved to new environments.
2. Yield increased as seed weight, plant height, and days to maturity increased.
3. Yield decreased as latitude increased.
4. Plant height increased as latitude, altitude, and days to maturity increased.
5. Days to maturity increased as altitude and latitude increase.

These summarizations are generalities and exceptions can be found for each. The results represent only the information available from these experiments and are subject to change with further research.

REFERENCES

1. Basnet, B., E.L. Mader, and C.D. Nickell. 1974. Influence of altitude on seed yield and other characters of soybeans differing in maturity in Sikkim (Himalayan Kingdom). Agron. J. 66:531-533.
2. Brown, D.M. 1960. Soybean ecology. I. Development--temperature relationships from controlled environment studies. Agron. J. 52:493-496.
3. Brown, D.M., and L.J. Chapman. 1960. Soybean ecology. II. Development- temperature-moisture relationships from field studies. Agron. J. 52:496-499.
4. Cartter, J.L. 1958. Time of planting studies. Northern states. Soybean Dig. 18(7):12-14.
5. Cartter, J.L., and T.H. Hopper. 1942. Influence of variety, environment, and fertility level on the chemical composition of soybean seed. U.S. Dept. Agr. Tech. Bull. 787.
6. Garner, W.W., and H.A. Allard. 1930. Photoperiodic response of soybeans in relation to temperature and other environmental factors. J. Agr. Res. 41(10):719-735.
7. Hartwig, E.E. 1954. Factors affecting time of planting soybeans in the Southern States. U.S. Dept. Agr. Circ. 943.
8. Hartwig, E.E. 1970. Growth and reproductive characteristics of soybeans (*Glycine max* L. Merr.) grown under short-day conditions. Trop. Sci. 12:47-53.
9. Hartwig, E.E. 1973. Varietal development. Pages 187-210 in Soybeans: improvement, production and uses. B. E. Caldwell, ed. Series No. 16. American Society of Agronomy, Madison, Wis.
10. Howell, R.W. 1956. Heat, drouth and soybeans. Soybean Dig. 16(10):14-17.
11. Hymowitz, T., J.W. Dudley, F.I. Collins, and C.M. Brown. 1974. Estimations of protein and oil concentration in corn, soybean, and oat seed by near-infrared light reflectance. Crop Sci. 14:713-715.
12. Johnson, H.W., H.A. Borthwick, and R.C. Leffel. 1960. Effects of photoperiod and time of planting on rates of development of the soybeans in various stages of the life cycle. Bot. Gaz.122:77-95.
13. Runge, E.C.A., and R.T. Odell. 1960. The relationship between precipitation, temperature, and yield of soybeans on the Agronomy South Farm, Urbana, Illinois. Agron. J. 52:245-247.
14. Thompson, L.M. 1970. Weather and technology in the production of soybeans in the Central United States. Agron. J. 62:232-236.
15. U. S. Naval Observatory. 1963. The nautical almanac, 1965. U. S. Government Printing Office, Washington, D.C.

DISCUSSION

R.K. JANA: Yield increases as days to maturity increased. When yield is converted to per unit time (day) basis, the reverse may be true. Which one is more convincing and scientific?

D.K. WHIGHAM: The "unit time" basis of production may be more scientific but each environment has a length of season which can be utilized for production. In practice, a farmer should select a variety which produces the most during a given season.

JANA: I think short duration varieties should be grown, because less risk is involved in management practices. What is your opinion?

WHIGHAM: Proper management is the key to all production and if the crop is managed properly risk is reduced. Short duration varieties have a place in many environments but not because there is less risk involved in management.

E.T. MMBAGA: Have you made any attempt to find the solution for eliminating the abortion of soybean flowers?

WHIGHAM: A considerable amount of work is being conducted along these lines by other groups but our program is not currently working on the problem of flower abortion.

S. MOUTIA: What is the position regarding commercially obtainable inoculum and is it possible to manufacture them widely?

WHIGHAM: U.S. *Rhyzobium* contains many strains. Australian inoculum is monostrain. *Rhyzobium* inoculum can be produced widely in India and Rwanda but is expensive and must be shipped by air.

M. VON OPPEN: Most developing countries are growing soybeans in mixed cropping patterns. Your evaluation trials test soybeans as a monocrop. Do you consider including mixed cropping trials also?

WHIGHAM: So far soybeans are tested in monocropping trials only, since many countries introduce soybeans as a monocrop. However, this problem will be given attention in the future.

W.J. KAISER: What precautions are being followed by INTSOY when seeds are sent to participating countries?

WHIGHAM: The seed qualifies for sale within and outside the United States and a phytosanitary certificate accompanies all shipments.

KAISER: Are seeds treated with seed-treatment fungicides and/or insecticides?

WHIGHAM: The seeds are treated with a seed-treatment fungicide.

KAISER: Are seeds tested for freedom from seedborne pathogens?

WHIGHAM: Special tests are not conducted to determine the freedom from seedborne pathogens.

H. MERCER-QUARSHIE: What is the relationship between yield and nodulation? You indicated in your paper that Hardee was the most consistent top yielder and yet Hardee is said to nodulate relatively poorly.

WHIGHAM: Good nodulation is essential to the production of high yields unless large amounts of nitrogen fertilizer are used. The variety Hardee is thought to be *Rhizobium* strain specific. If so, the inoculant used must include the proper strain because adequate nodules are formed.

L.K. OPEKE: Are seeds pre-inoculated with appropriate *Rhizobium* when sent out for that purpose?

WHIGHAM: No, we provide fresh inoculant for the cooperator to use at planting time.

A.M. CONJE: In any research organization there is always the problem of research allocation. Therefore, in initiating a new research project, a potential cooperator wants to know the chances of success of that new project. What, then, are the minimal environmental requirements to successfully grow soybeans?

WHIGHAM: Adequate water (75 or more cm during a season), moderate to warm temperatures (20^{o}-$40^{o}C$), and fertile soils with a neutral pH.

L. MCAULEY: Days to maturity and plant height are increased with increasing altitude and latitude. Yield is increased with increasing plant height and days to maturity, but is depressed with increasing altitude and latitude. How do you correlate these conclusions?

WHIGHAM: Altitude has an inconsistent effect on yield but yield did decrease with an increase in latitude. Therefore, altitude must have a stronger influence on yield than does latitude.

E. HERATH: At the nine locations tried out in Sri Lanka, the nine groups and growth habits could be classified in three plant types. Indeterminate tall, medium, and dwarf or compact types. Since most of the land is wasted, the true yield potential could not be judged when the spacing is 60 cm for all types.

WHIGHAM: Each country should conduct its own cultural trials to determine optimum spacings for any particular variety.

A. CAMERMAN: Do all the African countries participating in the INTSOY trial grow soybean on a large scale?

WHIGHAM: Most African countries cooperating with INTSOY do not grow soybean on a large scale.

CAMERMAN: For those countries which do participate, do they make their own inoculum or do they import inoculum?

WHIGHAM: INTSOY sends inoculum with the seed sent to participants.

S.D. AGBOOLA: One of the problems in the exchange of seed is its loss of viability relatively soon after harvest. Has this anything to do with varietal differences or lateness or earliness to maturity? How can viable period be extended.

WHIGHAM: The loss of viability is due to nonoptimum harvest and storage and can be best improved by better timing of harvest and optimum storage conditions.

AGBOOLA: What are the signs or indications of maturity? Have you determined a period of maturity for each variety during which you can harvest irrespective of whether the pods are dry or not? Or do you allow all the pods to dry before harvesting? Do all the pods mature uniformly?

WHIGHAM: Seeds mature as the pods mature, and brown or gray pods are the best field indication of maturity. Moisture percentage determination is a more accurate method and should be near 15 percent for harvesting and immediate storage. Not all pods mature uniformly, but the time lag is not usually very great.

R.B. DADSON: In both 1973 and 1974 trials there was a request to record plant stand at emergence and at harvest. Has this information been used to establish any correlations between seed weight and yield?

WHIGHAM: Plant stand and yield components have not been correlated.

H.A. VAN RHEENEN: What are the details on experiment design?

WHIGHAM: Randomized block with four replications.

VAN RHEENEN: And plot size?

WHIGHAM: Four rows wide and 6 meters long.

VAN RHEENEN: What was the spacing intra- and inter-row?

WHIGHAM: Rows were 60 cm apart and plants were 5 cm apart.

VAN RHEENEN: What was the fertilizer application for 1973 international soybean trials?

WHIGHAM: No nitrogen was recommended and a soil test was recommended to determine P and K needs.

T.I. ASHAYE: Any relationship between seed size and yield?

WHIGHAM: Yes, seed size increased as yield increased.

ASHAYE: Is increased yield due to size as number of seeds?

WHIGHAM: Size of seed was positively correlated with increased yield, but seed number was not recorded.

ASHAYE: Any relationship between size of seeds and quality?

WHIGHAM: Not in this experiment.

ASHAYE: Was irrigation applied in any of the experiments?

WHIGHAM: Yes, some experiments received irrigation.

G.F. NSOWAH: Have you established any correlations between the components of yield--namely, the number of pods, number of seeds, and seed weight?

WHIGHAM: There is a positive correlation between yield and seed weight. Seed and pod number were not recorded.

V.M. BHAN: In India, in two different seasons row spacings are different. In the rainy season 60 cm and spring season 30 cm. Should we not go for the row spacing that is best for the season in INTSOY trials?

WHIGHAM: For each environment one should develop his own cultural practice including row spacing, but for uniformity we should go for 60 cm standard row spacing.

Breeding Methodology for Tropical Soybeans

K.O. Rachie and
W.K.F. Plarre

Soybeans are already well established in the tropics at intermediate elevations and in the subtropics (20° to 30° N or S lat). An estimated 3.11 million metric tons of dry seeds, or about 6 percent of world production, were produced on 2.66 million hectares in the tropics in 1971. Most of this production (2.6 million mt) probably occurred at intermediate elevations in the tropics and represents a 5.3-fold increase over average production for 1961-65 in the same regions (4, 10). The major question is whether this valuable crop can be established in the low latitude, low elevation tropics. There is mounting evidence that soybeans perform well in the lowland tropics under favorable conditions and with good management practices. However, a combination of plant improvement, and optimum management and plant protection practices will be essential in developing a soybean industry. Economic inducement is highly likely, considering recent interest in soybeans on the part of African governmental agencies. However, there may be a problem of sustaining interest between the time of initiating production and establishing a processing industry.

OPTING FOR IMPROVEMENT

Any government or other agency interested in developing a soybean improvement program in regions where the soybean is a new and unfamiliar crop must recognize the risks involved. It is seldom wise to mount an improvement program without first making extensive economic surveys and having at least some rudimentary knowledge of crop performance in the areas where the soybeans will be grown.

The major considerations for policy makers and administrators in deciding whether to mount soybean improvement programs are the availability of funds and the program level necessary to accomplish their objectives and to train scientific and technical staff. There are at least three basic types of programs that can be considered:

1. Include soybean improvement as an additional responsibility in an existing program, usually in a general pulses or oilseed crops program;
2. Mount a separate one- or two-man (scientist level) program;
3. Establish a fully developed program headed by scientists in disciplines including at least agronomy, breeding, and plant protection.

In considering these alternatives, experience suggests that option number 1 is seldom effective. It usually involves an added burden for a scientist with other major responsibilities and who has neither the interest nor experience to investigate the new crop.

There is considerable merit in starting a new program with one or two scientists such as an agronomist and plant breeder. They become protagonists for soybean, thereby assuring it the best chance of succeeding. Later the program can expand in relation to developmental progress and its economic potential. Such expansion must include extended testing in the country's potential growing areas and strengthening of the program staff and facilities.

The importance of training to allow the scientists to gain experience in growing soybeans is emphasized. In 1975 the International Institute of Tropical Agriculture (IITA) will offer a 12 week course in grain legume (including soybeans) production and improvement. This will focus on problems and methodology of soybean improvement in the low, humid tropics.

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W.K.F. PLARRE: Visiting Scientist (Soybean Breeding): International Institute of Tropical Agriculture, Ibadan, Nigeria.

CLIMATIC CONSIDERATIONS

There are two basic kinds of climate in the continental tropics that can profoundly influence the selection of varieties and management practices for soybeans. While elevation and proximity to the sea are important, rainfall patterns also tend to follow the latitude with a definite bimodal pattern occurring at low latitudes and gradually merging into one extended rainy period at higher latitudes (greater than 10^{o} to 12^{o}).

As a typical example of the marginally humid tropics, Ibadan, Nigeria at 7024' N lat and 300 m elevation receives about 1,270 mm of rainfall annually. Rains may start in late March, reach a peak in June (190 mm), decline to around 110 mm in August, sharply rise again in September (185 mm), and terminate before the end of October (Fig. 1). On an avêrage, 670 mm of rain are received from April to mid-August, and 416 mm from mid-August to the end of October, representing 86 percent of the year's total precipitation. Insolation follows the rainfall pattern, ranging from about 300 to 500 cal/cm^2/day throughout the year, with mean lows of about 400 cal/cm^2/day during June-August and approaching 500 cal/cm^2/day in April and late October-November (6, 7).

Soybean breeding in the tropics has tended to follow seasonal rainfall patterns. Thus, short season, day length insensitive genotypes with 80 to 100 days' duration perform well in the distinct bimodal rainfall regions and in the shortened single-season areas. Long season or day length sensitive strains with 4 to 5 months' duration are grown in the middle belt (aboue 9^{o} to 11^{o} lat) having a single extended rainy season with more than 800 mm of precipitation. Because long duration, day length sensitive strains, especially from the Asian tropics, tend to grow vegetatively for a long time, they remain exposed to various hazards over a much longer period and sometimes occupy land when a second crop should be taken by growing a short season crop. If near maximum yields are realized from growing periods of 100 to 110 days, is it necessary to breed long duration strains? With recent advances in land preparation and tillage, and using both general and selective herbicides, even short or medium duration strains can be planted at such a time as to mature at the beginning of the dry season--the most desirable period for producing high quality grain legume seeds.

PROBLEMS IN BREEDING METHODOLOGY

Nearly all plants fail to reach the full biological potential in the low, humid tropics. Soybeans are no exception but, at least under Ibadan conditions, they have greater productivity potential and fewer insect pests or diseases than some other leguminous species--notably cowpeas. Investigations at IITA and other centers in the tropics reveal a broad range of soybean genetic stocks from both temperate and tropical regions with yields approaching practical biological limits imposed by nitrogen nutrition. (A vigorous crop producing 3,000 kg/ha requires about 280 kg N per ha). Moreover, there appears to be little need for extending crop duration beyond 100 to 110 days in the lowland tropics (Tables 1, 2). Thus, plant improvement work should probably focus on stabilizing high levels of productivity and improving handling and processing characteristics.

Evaluation of the Breeding Program

In view of the above statements the major breeding and management problems that influence the breeding program at IITA are: environmental "insensitivity," improvement of agronomic characters and seed quality, efficiency of nitrogen fixation, and economic factors.

Environmental "insensitivity." This includes primarily day length and temperature insensitivity. It also includes wide adaptability including a broad range of tolerance to stress factors, diseases and pests.

In the lowland humid tropics soybean cultivars are preferable that show no response to short day conditions of the equatorial region as well as to the longer day length of areas in which the photoperiod is extended to 13.5 h (12^{o} to 13^{o} N and S lat, respectively). Effects of night temperatures are of great interest to the IITA program. Most important are cultivars found to be invariant to the ranges of day length and low night temperatures. From the tested cultivars, Grant, for example, is a desirable genotype (6).

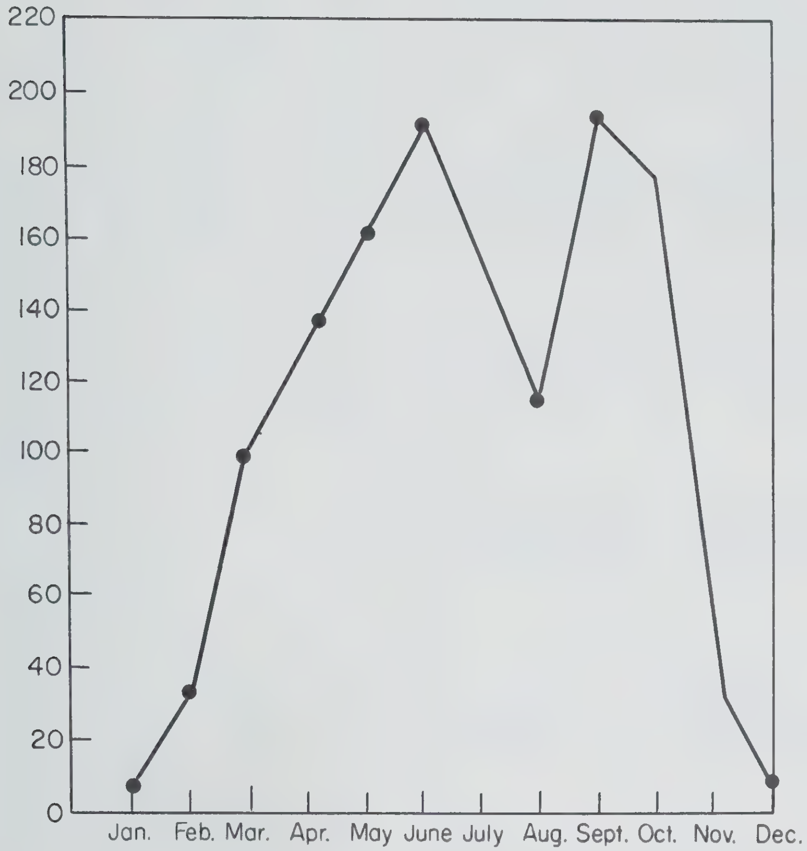

Fig. 1.
Mean monthly rainfall at University of Ibadan, Nigeria, 20-year average.

The primary stress factor--even in the low tropics--is probably moisture. Water stress between emergency and first flowering has marked effects on seed yield. But a lack of moisture at the end of the season also has an influence. This is true in the second growing season at IITA. Irrigation after the rains stop extends the growth duration and increases the yield. However, yield response differs. Some of the cultivars tested have equivalent yields and others with high moisture response are capable of maximal yields only if the water supply is adequate for 100 days or more. This is easily tested in a split plot trial, which can be used as a special screening method to select moisture tolerant genotypes (Fig. 2).

Tolerance to high soil temperature is important during emergence. Because periods of 36°C or higher soil temperature can occur during the middle of the day in the first growing season, a reduction in seed emergence can result. Special investigations of this problem were started by our physiologist, H.C. Wien.

Other stresses include low soil fertility, low pH, high pH, and salinity.

The serious diseases at Ibadan are bacterial pustule *Xanthomonas phaseoli* var. sojense), viruses (green mottling and dwarfing types), and seedling and leaf blights (*Pythium* and *Rhizoctonia* spp.). R.J. Williams, pathologist, has observed loss in productivity of 15 percent or more from bacterial pustule in susceptible strains (6, 7). No disease resistant cultivar has been found among introduced stocks but several resistant lines can now be selected (Table 3).

Table 1. Yield in kg/ha of cultivars entered in the uniform soybean trials for two seasons in Ghana and Nigeria, 1972-1973.

Cultivar	Nigeria				Ghana		Mean	Relative yield
	Bende 1972	IITA 1972	IITA 1973		Kpong 1972	Legon 1972		
	Season		Season		Season			
	First	First	First	Second	First	Second		
Bossier	3,653	2,260	1,960	1,626	2,140	951	2,098	115.5
Imp. Pelican	3,396	2,483	1,465	1,247	3,112	789	2,082	114.7
CES 486	2,212	3,000	--	1,124	2,479	1,585	2,080	114.5
CES 407	2,619	2,803	--	1,511	1,483	1,230	1,929	106.2
Chung Hsing No. 1	1,656	2,565	1,450	1,370	2,761	1,307	1,851	101.9
Chippewa 64	1,747	1,851	1,663	1,693	2,836	1,173	1,827	100.6
Kent	2,472	1,641	1,887	1,076	3,137	687	1,816	100.0
IGm 393(S)	1,858	2,078	1,722	1,465	1,934	909	1,661	91.5
Clark 63	1,987	1,163	1,623	--	2,479	697	1,586	87.3
Amsoy	1,576	1,100	1,530	--	2,648	370	1,445	79.6
Shelby	1,615	1,661	1,098	--	2,028	725	1,425	78.5
Hale 3	1,433	863	1,433	1,276	2,817	409	1,372	75.6
Hawkeye	963	1,450	1,336	--	1,728	384	1,172	64.5
CNS	878	1,713	--	785	1,446	387	1,042	57.4
Mean	2,005	1,902	1,561	1,317	2,359	829	1,670	

Table 2. Characteristics of the cultivars entered in the uniform soybean trials for two seasons at International Institute of Tropical Agriculture, Ibadan, Nigeria, 1973.

Cultivar	Days to flower		Days to maturity		Plant height (cm)		Bacterial pustule[a]	Shattering, days after full maturity
	Season		Season		Season		Season	
	First	Second	First	Second	First	Second	Second	Second
Bossier	37	37	102	89	50	50	2	8
Imp. Pelican	36	37	103	86	104	78	5	4
CES 486	45	42	105	88	--	67	4/5	5
CES 407	44	42	105	89	--	72	5	7
Chung Hsing No. 1	39	37	100	86	67	62	6	3
Chippewa 64	37	35	103	85	95	71	5	6
Kent	27	29	90	84	56	48	3	5
IGm 393(S)	36	36	93	84	111	66	4	3
Clark 63	42	--	99	--	54	--	-	-
Amsoy	28	--	86	--	55	--	-	-
Shelby	28	--	87	--	48	--	-	-
Hale 3	31	29	87	85	29	28	3	5
Hawkeye	27	--	84	--	46	--	-	-
CNS	30	84	83	83	26	29	2	0

a/ o = immune; 6 = highly susceptible.

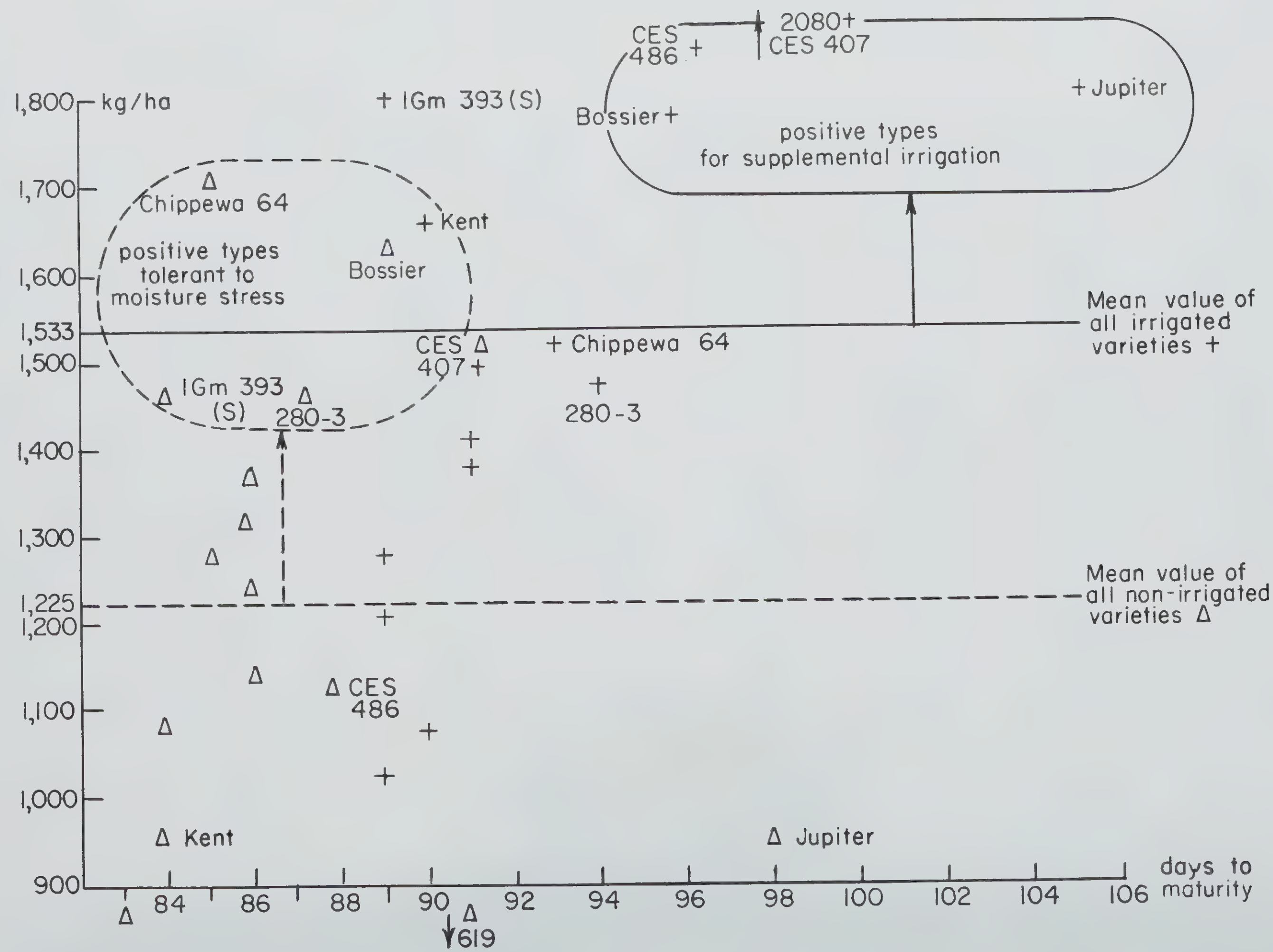

Fig. 2. Seed yield in relation to maturity for 14 soybean cultivars grown under irrigation and rain-fed conditions, 1973.

Table 3. Yield in kg/ha and other characteristics of high performing new strains tested in two seasons of 1973 at International Institute for Tropical Agriculture, Ibadan, Nigeria.

Strain No.	Absolute yield		Mean relative yield	Days to maturity		Bacterial pustule[a/]	Shattering days after maturity
	first	second		first	second	second	second
245-4	2,075	2,059	142.6	92	88	0/1	2
220-1	1,894	1,599	120.5	99	86	6	3
282-2	1,863	1,578	118.7	88	82	6	8
188-3	1,640	1,696	115.0	94	87	1	3
305-2	1,866	1,429	113.7	89	81	6	12
85-1	1,491	1,573	105.7	87	80	4	11
Kent	1,701	1,199	100.0	93	81	3	6

a/ 0 = immune; 6 = highly susceptible.

Several foliage, flower, and pod insects cause apparent loss of leaf area, yield, and seed quality at Ibadan. These include various larvae (*Laphygma* spp.) on the foliage, thrips (*Taeniothrips* and *Seriocothrips* spp.) in the flowers, and *Laspyresia*. Coreids and *Callosobruchus* sp. attack the developing pods and seeds. Preliminary investigations by S.R. Singh and M.O. Ogunlana at IITA suggest variation in susceptibility among genotypes. Bilomi 3, Wilson Black, Black Malta, Semmes, and Masterpiece, for example, show a conspicuous tolerance.

Improving agronomic characters. Several agronomic characters appear amenable to genetic improvement, including shattering, lodging, mechanical harvesting, and preharvest weathering.

Some strains shatter almost immediately (1-2 days) after ripening, compared with 8-12 days for others, in the hot, dry season at Ibadan. The large variability in this character gives a great chance for successful screening (Tables 2, 3; Fig. 3).

If soybeans are planted in large fields, mechanical harvesting by combine becomes a necessity. Therefore suitable, erect genotypes, resistant to lodging and shattering, and also characterized by a pod set higher from the ground must be developed. As can be seen from Fig. 4, there is progress in the selection for this agronomic character.

Vigorous and rapid growth to cover the land quickly and develop a good root system is considered important, but not at the expense of lodging with consequent reduction of yields and deterioration of seed quality. In the material now available at IITA we have tall, erect types with excellent stiffness of stem (Fig. 5).

Fig. 3. Genetic improvement of soybeans for resistance to shattering. Segregating bulk No. 4266 (74D) selected from TGm 210. Left to right, shattering resistant (10 days), slightly shattering, completely shattering three days after maturity.

Fig. 4. (at right). Genetic improvement of soybeans for suitability for mechanical harvesting. Left, Improved Pelican; right, strain No. 2375 (73S), selection from TGm 294 with high pod setting from the bottom.

Fig. 5. Genetic improvement of soybeans for resistance to lodging. Left, lodging susceptible strain No. 1093 (73S) selected from TGm 241; right, lodging resistant strain No. 1094 (73S) selected from TGm 236.

Deterioration of seeds during and immediately following ripening, causing reduced quality and germinability, is an important problem when harvest occurs during humid weather. This is often the case in the first growing season at IITA. There are extreme differences in the percentage of bad seeds in the same genotype grown in two different seasons (Table 4). The category of bad seeds includes all damaged seeds (split, broken, insect damaged), those not completely developed (flat, wrinkled), and seeds contaminated by fungi (purple stained). There is some variability among available genetic stocks in susceptibility to purple stain caused by *Cercospora kikuchii* (Fig. 6, 7).

Improving seed quality. Many external factors (environment) and internal factors (genes) are responsible for producing good seed quality. There are many points of view on how seed quality can be defined. Only two aspects are mentioned here--improved seed for human consumption and for storability.

In the improvement of seeds for human consumption, aside from the search for high sulfur-bearing amino acids and reduced levels of metabolic inhibitors (trypsin inhibitor), which should probably remain largely with major centers, there are some seed quality factors requiring attention. For example, quicker cooking time and loss of beany taste in special food products. Four stages of screening for protein quality are carried out in the Biochemistry Laboratory at IITA: First, parameters of protein quality--total nitrogen, total sulfur; second, protein quality--total protein, sulfur-amino acids; third, nutritional value--amino acid composition, animal feeding; fourth, other quality factors.

Retention of viability in storage is of great importance under tropical conditions. To determine the rate of decline of germination with length of storage under ambient temperature conditions, special investigations were started at IITA by agronomist D. Nagju and physiologist H.C. Wien (7). To achieve storage objectives it may be necessary to reduce seed size and, perhaps, lower oil content somewhat according to Hartwig (5). Selection for small round seeds--100 seed weight less than 11 g--has started (Fig. 8). Because seed size is an important yield component the loss of the seed weight must be compensated by selection of a high number of seeds per pod.

Fig. 6. Selection of soybeans for resistance to preharvest weathering. Seed samples first season 1973. Left, strain No. 305-2; right, Bossier.

Fig. 7. Seed samples from Bossier selected for resistance to preharvest weathering. Left, second season; right, first season 1973.

Table 4. Differences in seed quality in distinct cultivars and lines grown during the first and second seasons at International Institute of Tropical Agriculture, Ibadan, Nigeria, expressed as percent of weight of bad seeds after machine threshing.

Cultivar per line	First season 1973	First season 1974	Second season 1973
Kent	64.5	23.0	10.7
Bossier	58.9	8.0	8.4
195-3	33.8	12.0	19.3
85-1	29.1	22.0	7.2
305-2	24.1	7.0	9.1

Efficiency of nitrogen fixation. This area requires intensive study in the tropics. Work done at Rothamsted Experimental Station in England by Dart (3) demonstrates the greater effectiveness of certain *Rhizobium* strains, such as Sm 1b from Brazil, which fixed more than twice as much nitrogen at high soil temperatures (33°C) than temperate strains such as CB 1809. In this area major advantages will accrue to soybean varieties possessing genetic factors favoring infection by more effective *Rhizobium* strains. Careful investigations must be made under natural soil conditions since very little is known about environmental effects, rhizobial genotypes, and biological competition under tropical conditions.

Economic factors. Encouragement of any crop, including soybeans, will not be successful by unrealistic pricing policies. Normally, a government desiring to promote a crop or commodity is willing to subsidize production at the outset. This should not be necessary with present world prices of soybeans approaching $300 per metric ton. Holding internal market prices at a third of this value is unrealistic, does not benefit the general economy, and greatly encourages smuggling.

Adapted Methodology

Traditional methods of breeding, based on simple or multiple recombination followed by advancement to various levels of homozygosity, have served soybeans well in the past and will continue to do so for some time to come. However, newer methods of both varietal and population improvement promise more rapid and efficient rates of advancement. The important point is that plant breeding is a "numbers game" and rate of progress becomes a factor of the range of genetic diversity utilized, extent of recombination effected, numbers of segregants grown out, and generations completed per annum. The last factor is particularly significant in the tropics because, with a favorable climate and irrigation, three successive generations can be completed each year. This is a tremendous advantage over temperate regions where only one field generation is possible a year.

Varietal improvement. The soybean breeding program at IITA started in 1970 and was characterized by plant introduction. Part of the world collection was evaluated to select suitable genotypes adapted to the lowland humid tropics. Emphasis soon shifted to selection of introduced segregating lines. Strain building is going on and a number of promising lines are tested in yield trials (Table 3). Methods of varietal improvement receiving greater attention in recent years include multiple crossing, crossing at the F_1 level, bulk pedigree, and single seed descent (1). Multiple crossing and crossing at the F_1 level are similar systems of recombination and are designed to increase the rate of accumulating additive gene action and breaking of undesirable linkages. Bulk pedigree and single seed descent advance generations with a minimum of record keeping. The latter allows retention of genetic variance while growing out fewer plants, thereby increasing the number of recombinations that can carried.

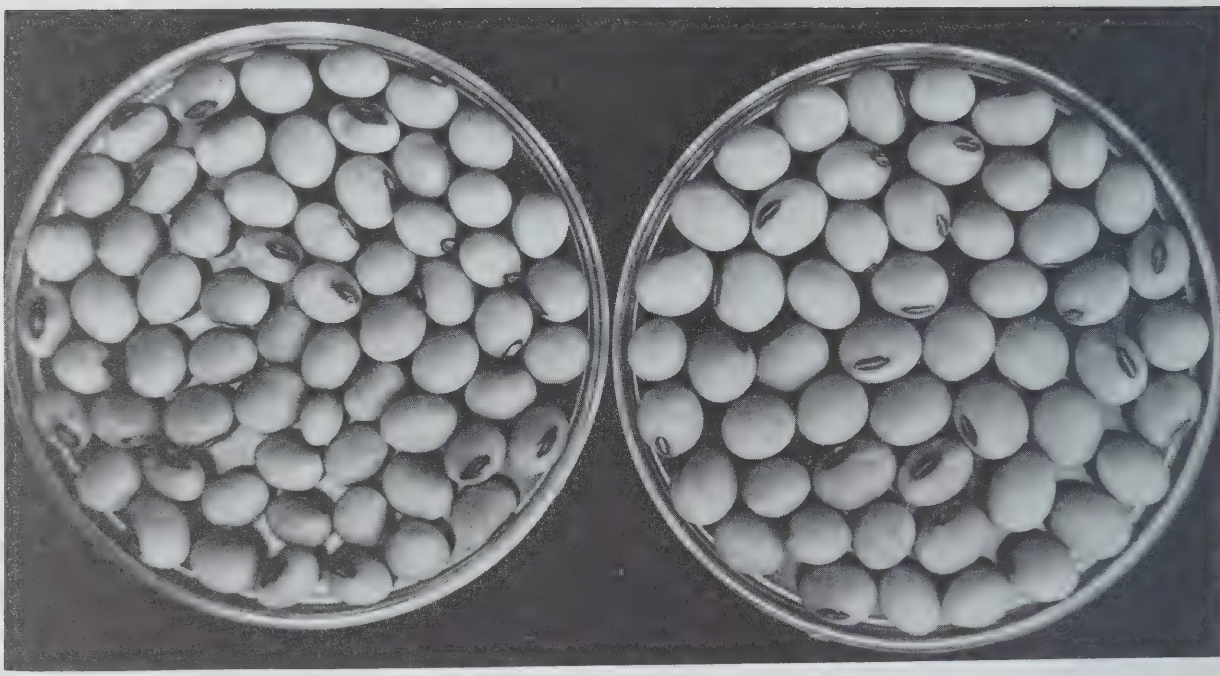

Fig. 8. Selection of soybeans for seed size. Seed samples. Left, small-seeded strain No. 4345 (74D), selected from TGm 260-3; right, big-seeded strain No. 305-2.

Population improvement. The most efficient method for improvement of quantitative characters, including yield, is population improvement based on recurrent selection principles. Although mainly confined to outcrossing species in the past, there are new methods for adapting population improvement to the self-pollinated species, utilizing both hand crossing and outcrossing mechanisms. A recurrent selection method utilizing hand crossing for self-pollinated crops was outlined by Jensen (8). More recently the possibilities for utilizing mass selection to improve characters with low heritability in wheat and barley was studied by Redden and Jensen (11). They concluded that mass selection even at a low level of outcrossing could be a useful breeding tool for inbreeding species, provided that the additive component of genetic variance is important.

In breeding of cowpeas at IITA a modified system of S_2 selection is used based on four generations per cycle to be completed in one year (possible in medium to short duration cowpeas at Ibadan). This is based on utilizing genetic male sterility (ms 2 ms 2) discovered at IITA, with recombination effected either by hand crossing or insect pollination. We have recently discovered insect pollination can be highly effective at least in the first rains season. While the recombination procedure is somewhat complex, the generations for one cycle are described as follows:

Generation	*Season*	*Description*
1	Dry-irrigated (Nov.-Feb.)	Recombination by hand or "naturally" by insects.
2	Early first season (March-May)	Grow out of F_1's. Discard weak, diseased plants.
3	Between rains (June-Aug.)	Grow out S_1's. Select best 100 families, discarding inferior plants for S_2 testing.
4	Second rains (Sept.-Nov.)	Replicated tests of 100 S_2's in three environments. Select best 10 percent based on yield tests for recombination.

A similar system can be developed for soybeans as a modified S_1 testing method (three generations per year). It is proposed to utilize either hand crossing or an outcrossing mechanism such as male sterility (2) and delayed dehiscence closely linked with the puberulent character. The latter system appears interesting as we have achieved a 10 percent level of outcrossing and the F_1's are easily recognized as seedlings because they are pubescent.

Figure 9 illustrates the procedure of a population improvement program. The selection work is oriented on tests for combining ability. In a preliminary trial we found a vigorous, tall, elite plant with smooth pods, yellow seeds, and medium maturity. The original puberulent material (TGm 31) is characterized by smooth pods, brown seeds, earliness, and short growth habit. There is a drastic change in many characters after outcrossing and segregation (Fig. 10, 11). Seeds of this mother plant will be used as a basis for an improvement population and further selection in the progeny.

Seed multiplication. Results indicate that soybeans will perform well in the lowland tropics. From the breeding program at IITA and other sources, promising new strains will become widely available. The major problem at present will be to supply adequate quantities of good quality seeds of assured genetic purity and high germinability. National schemes in either the private or public sector must be encouraged to undertake this important function.

Adapted Technology

Land preparation. The foremost requirement in soybean field research is to do a "first class job" of farming. This starts with selection of good, uniform land, avoiding light textured soils. There must be careful and uniform tillage operations timed to obtain a uniformly friable seed bed and to maximize weed kill. Fertilizers are applied either before or after the basic tillage (plowing or chiseling) operation. At IITA we plow down the fertilizers to eliminate a compacting operation after the basic tillage operation. Possibilities for zero tillage have also been demonstrated for soybeans at IITA. This requires using general herbicides (paraquat) followed by preemergence chemicals and hand weeding. The advantages are several, especially decreased erosion, increased infiltration, and reduced power/energy requirements for land preparation.

Planting and inoculation. The first requirement in proper evaluation and yield testing of soybeans is a good stand on most cultivars. This means one plant every 3 to 4 cm in rows 50 to 75 cm apart. If high soil temperatures (above 34° to 35°C) are expected it helps to spread a light straw mulch over the row. The mulch reduces soil temperatures and crusting during emergence, which may require 5 to 6 days. As soon as the seedlings have emerged the mulch must be removed. Application of fresh inoculum of *Rhizobium japonicum* is essential in most African soils where soybeans have not been successfully grown in the recent past. Because inoculum loses its viability quickly at high temperatures, we store our stocks under refrigeration and treat the seeds immediately before planting. A suspension of inoculum with water and a sticker is carried in plastic squeeze bottles and seeds are treated directly in the seed packet.

Weed and pest control. Investigations at IITA indicate that good weed control for about 30 days after planting is adequate to attain near optimum soybean yields. We have not used preemergence herbicides such as chloramiben and Lorox in our breeding nurseries or yield trials as there is still limited information on chemical X genotype interactions.

Most important insect damage is likely to occur from flowering to ripening, and regular spraying should be done during this critical period if not required during the vegetative stages. In 1974 we adopted the regular use of Azodrin (20 ml/10 liters of water) alone on a 7 to 10 day schedule during the critical period with highly satisfactory results. Another effective insecticide is Surecide but it is still under experimental testing.

Field plot technique. Growing out large numbers of breeding lines and extensive varietal testing taxes the organizational and record maintaining ability of the best of supporting staffs. There are at least two ways to labelling field plots--marking the pegs directly, or utilizing tags (metal, plastic, or paper). Often ink or other marking materials fade. At IITA we map our fields carefully and use heavy paper labels marked with waterproof ink on both sides and dipped, together with the string, in molten wax to which small amounts of an insecticide and a fungicide are added. Tags treated in this way easily last 3 to 4 months in seasons of alternating heavy rainfall and bright sunshine. Field pegs can be of inexpensive split bamboo, but these should be short (about 30 cm) if tractor cultivation is anticipated.

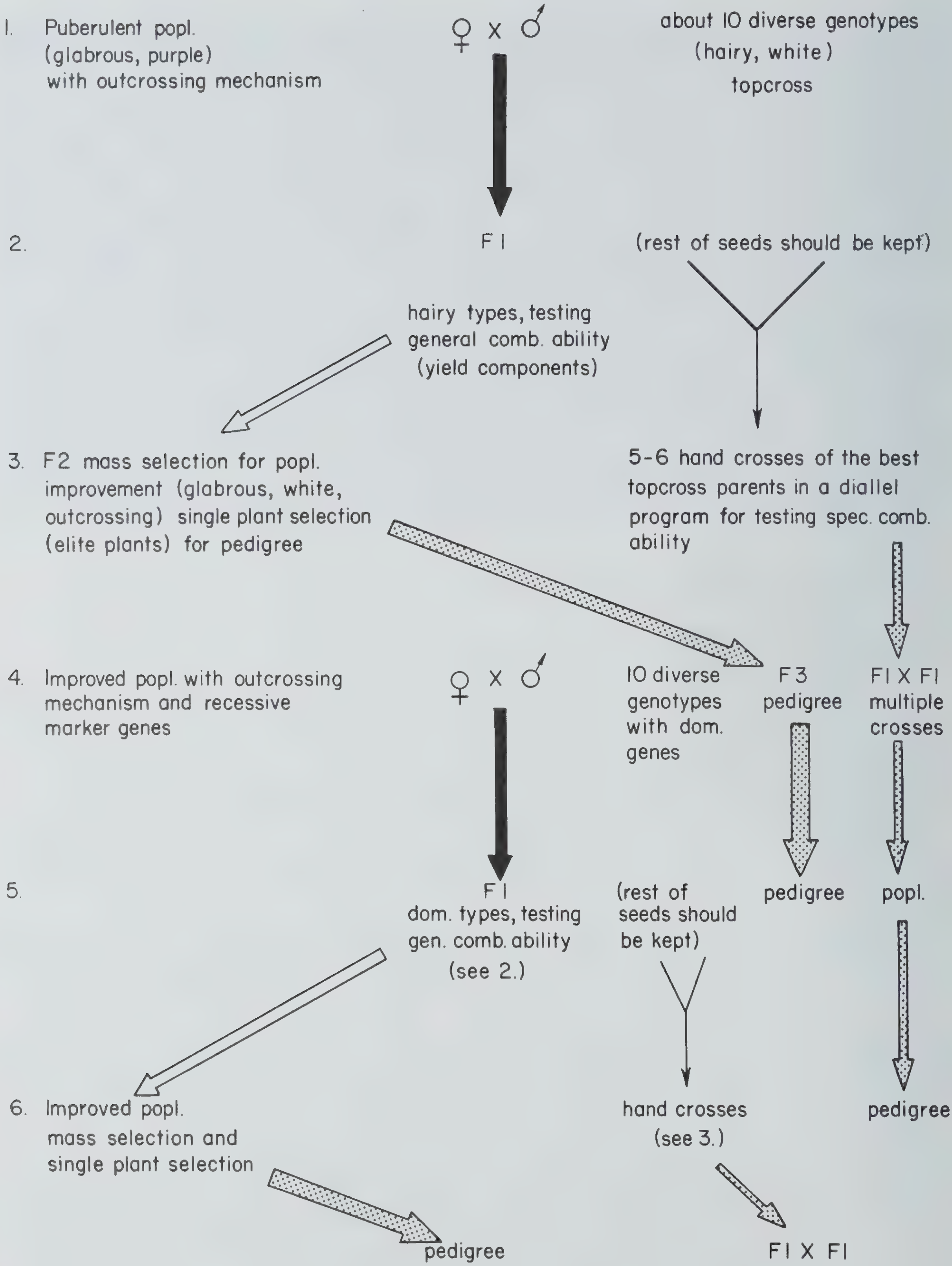

Fig. 9. Soybean population improvement model.

Fig. 10. Change in characters after outcrossing and segregation. Left to right, hairy type; glabrous type (selected from TGm 31); male sterile type, selected in line 103-1 (1972F).

Harvesting-threshing-storage. Yield trial and bulk seed increase plots are harvested by cutting the plants at the ground line with a power scythe, mower, or machete. The plants are tied into bundles or bagged in large gunny bags, dried in the sun or artificial dryers, and threshed by beating the pods in a bag with a stick or with powered experimental threshers. Thresher cylinders are slowed to reduce cracking. In the humid tropics storage of soybean seed must be handled carefully. Special equipment required for storage over a longer period is mentioned below in the discussion of equipment requirements.

Field evaluation. Comparatively little evaluation is done in early generations at least through the F_4 stage. On late generation stocks, basic germ plasm, yield trials, and other experiments we may record data on field germination, days to first flower on 50 percent of the plants, days to first ripe pods, mature plant height, incidence of disease (and insects if this was the purpose of the experiment), shattering, lodging, and total dry matter, in addition to dry seed yields. In some cases we also record nodes and pods per plant, seeds per pod, seed size, and certain descriptive characters.

Equipment requirements. Assuming that land preparation and weed and pest control are adequately taken care of, soybean breeding and agronomic experimentation does not require much equipment. In fact, in developing countries with adequate and inexpensive labor, it is frequently much easier and less troublesome to do most operations by hand. If it is necessary to mechanize, simple, rugged equipment should be selected that is easy to service and repair. Among the most essential equipment for field operations are: weighing and measuring instruments, devices for moisture testing and planting, tools and machines for cultivation, harvesting, drying, and threshing, and facilities for seed storage.

Fig. 11. Population improvement in soybeans through outcrossing and segregation. Left to right, Improved Pelican, original type TGm 31, and a selected vigorous line from TGm 31.

Weighing instruments should include a good swinging pointer balance of 5 kg capacity and accurate to 1 g, spring milk scales (30 kg capacity), and gram scales accurate to 0.1 or 0.01 g. Measuring instruments include tapes (30 m), meter sticks, and rules. Also convenient are direct reading calipers. Moisture testing can be done quickly with an electrical resistance device or by oven drying to a constant weight.

Several different kinds of tractor mounted or hand-push seeders are available for planting but hand seeding or "dibbling" is simpler and easier to control when labor is available. Tractor cultivation with some hand weeding within the row is highly efficient for interrow cultivation. The equipment, tools, and machines used for harvesting and threshing have been described above.

Special attention must be paid to crop drying and seed storage. Availability of reasonably large-scale crop drying facilities during humid weather or in areas with constant high humidities permits year-round cropping (with adequate moisture or irrigation). Moreover, it results in rapid drying and much better quality seeds than obtained otherwise. If necessary, harvested wet material put into open mesh bags can be dried within 48 hours with a temperature not higher than 46°C.

Germinability of soybeans tends to deteriorate rapidly with high or fluctuating temperatures and high humidities. Recent studies suggest increasing seed moisture content may be more detrimental than fluctuating or high temperatures. The best solution appears to be drying seeds to a low moisture content (7 to 10 percent) and storing in sealed containers when environment-controlled rooms are available. However, seed viability will be retained for reasonably long periods (2 yr or more) when seeds can be stored in air-conditioned rooms. These should be insulated and moisture-proofed on all sides and fitted with an air-conditioner and dehumidifier (if necessary) to maintain the temperature below 25°C and humidity below 60 percent relative humidity. Infrequent openings and a standby air-conditioner can improve the reliability of the system.

For long-term storage of small lots of exceptionally valuable genetic stocks, subfreezing temperatures obtained in a simple home freezer may be the most economical and practical means of storage. If seeds are reduced to a low moisture content and sealed in moistureproof containers they should last indefinitely (9).

Supplies. If a crossing program is carried out, some special tools are needed. Soybean flowers are tiny and difficult to emasculate and pollinate without magnification and fine-pointed tweezers. Magnifiers mounted on the head (or as eye glasses) are preferred as they leave both hands free.

It is virtually impossible to operate a plant breeding program without adequate supplies of seed packets, fabric and plastic bags, string, field pegs, tags (various), pencils, marker pens, note paper, clips, and other items. Often these materials are not available locally or are much less expensive when purchased abroad. Administrative procedure is frequently cumbersome, which, together with delays in importation, results in several months' lag time before these materials become available. This situation necessitates careful planning together with interim contingency measures.

As previously noted the initial capital requirements to establish a soybean breeding program are not excessive. If purchases are made in the international market, most of the equipment requirements except field tillage machinery (tractors, plows, harrows, and so on) could be purchased for $8 to $10 thousand. This list would even include air-conditioners and dehumidifiers for seed storage, but not the cost of sealing and insulating the seed store itself and construction of shelving. In addition to initial equipment requirements an annual outlay for replenishable supplies would probably be $4 to $5 thousand.

CONCLUSIONS AND SUMMARY

The decision to mount a soybean improvement program should be based on the potential importance of the crop to the country and region and the availability of resources to support this effort. While there is much to commend making a modest start and encouraging further growth as progress is made, there is a certain minimum level below which little will be accomplished. One or two full-time scientists (plant breeder and agronomist) with full logistic support are required to make any meaningful progress over a limited range of environmental conditions.

The first step in any crop improvement program is to elucidate the objectives (at least for that point in time), define the major constraints, and outline a plan of action. Good crop husbandry is the first order of priority in initiating field experimentation. For the low-humid tropics, weeds, pests, and diseases are likely to be more limiting to productivity than moisture stress or low soil fertility levels. The use of seed dressings or seed furrow applications of new systemic fungicides and insecticides in addition to minimal spray applications of insecticides during fruiting will pay handsome dividends. Application of effective populations of *Rhizobium japonicum* at planting is essential in soils without a recent history of successful soybean cultivation.

Conventional plant breeding methods may be the most effective for the near future. Within varietal improvement breeding schemes, multiple crossing and crossing at the F_1 level followed by bulk pedigree or single seed descent procedures merit serious consideration. Population improvement schemes are currently under development and could become important within the next two years.

Plant breeding is a "numbers game" with the rate of progress depending on the genetic diversity used, recombinations made, segregating materials grown out, and generations advanced per year. Since these operations are often carried out by large numbers of partially trained, semiliterate laborers and assistants it is essential to establish and maintain a simple, straightforward set of procedures easily understood by everyone.

In developing regions and remote areas, labor should be substituted for sophisticated equipment whenever possible, to reduce the costly interruption of operations through breakdown, unavailability of service, or loss of electric power. Simple, ruggedly constructed, mechanically operated equipment should be preferred over that dependent on electricity; but electrically powered machines are more reliable than petrol engines. Supplies such as paper bags, tags, pencils, note sheets, slips, and other items should be ordered in quantity and several months--if not years--before they will be needed.

Every scientist should become acutely aware of the economics of pay-off in his research. For example, in soybean breeding the costs of crossing and growing out large numbers of breeding lines is much less expensive or troublesome than yield testing. Moreover, preliminary testing in smaller plots and with fewer replications is less expensive than advanced trials. In designing trials and determining the numbers of entries at each level of evaluation, several factors besides yield must be considered. Ultimately, a close familiarity with the crop and its great range of variation and a basic understanding of the program procedures and objectives are essential in achieving meaningful progress in this or any other crop management program.

REFERENCES

1. Brim, C.A. 1966. A modified pedigree method of selection in soybeans. Crop Sci. 6:220.
2. Brim, C.A., and M.F. Young. 1971. Inheritance of a male sterile character in soybeans. Crop Sci. 11:564-566.
3. Dart, P.J. 1973. Root nodule symbiosis and tropical grain legume production. Pages 185-197 in Proceedings first IITA grain legume improvement workshop. International Institute of Tropical Agriculture, Ibadan, Nigeria.
4. Food and Agriculture Organization. 1972. Agriculture production yearbook. Vol. 25, pp. 175-176. Food and Agriculture Organization of the United Nations, Rome.
5. Hartwig, E.E. 1973. Report of soybean improvement research. Page 36 in Proceedings of the first IITA grain legume improvement workshop. International Institute of Tropical Agriculture, Ibadan, Nigeria.
6. International Institute of Tropical Agriculture. 1972. Report, grain legume improvement program. International Institute of Tropical Agriculture, Ibadan, Nigeria.
7. International Institute of Tropical Agriculture. 1973. Report, grain legume improvement program. International Institute of Tropical Agriculture, Ibadan, Nigeria.
8. Jensen, N.F. 1970. A diallel selective mating system for cereal breeding. Crop Sci. 10:629-635.
9. Rachie, K.O., and T.N. Khan. 1972. Effect of various drying and freezing treatments on the viability of some grain legume seeds. SABRAO Newsltr. 4(2):79-84.
10. Rachie, K.O., and L.M. Roberts. 1974. Grain legumes of the lowland tropics. Adv. Agron. 26:1-132.
11. Redden, R.J., and N.F. Jensen. 1974. Mass selection and mating systems in cereals. Crop Sci. 14:345-350.

DISCUSSION

E. ASENIME: Have you had uniform maturity among some of the varieties that you had mentioned in your presentation or did you have several pickings during the harvesting period?

W.K.F. PLARRE: In our varieties and also in the newly developed lines we have uniform maturity. There is no segregation in this character. We do not have several pickings. There is only one harvest time for each variety or line respectively.

E.V. DOKU: How would you rank day insensitivity as a selection criterion against your other criteria, such as adaptation to moisture stress, high soil temperature, and so on?

Supplementary question: Don't you think day insensitive material will be difficult to obtain since almost all soybean cultivars are, in some measure, photosensitive?

PLARRE: All the characters you mentioned we can summarize under the term "environmental insensitivity." All these criteria have to be considered and all of them need great attention in our breeding program; but day-length insensitivity has a certain priority and all our new lines will be tested in their day-length reaction by our physiologist.

I agree to your supplemental question that there are difficulties to obtain complete insensitive cultivars, what we call "neutral" genotypes. Perhaps it is impossible to get them. We want to have insensitive types within the limitation between short days such as we have near the equator, and long days with about 13-1/2 hours such as we find at the 18^{o} latitude. This belongs to our program to develop adapted genotypes for these areas. We do not breed for higher latitudes.

A. CAMERMAN: Why is seed color important in soybean breeding?

PLARRE: For insect tolerant genotype it has been found that black or brown seeds are less susceptible, especially to pod borer. In terms of quality, the yellow seed is better. In terms of susceptibility to fungal disease, the seed color does not make a great difference.

G.F. NSOWAH: How do the CES407-486 varieties compare with Bossier, Improved Pelican, and Kent with respect to yield during the main and minor season?

PLARRE: For all these varieties the figures are published in our Grain Legume Annual Report 1973. On the average the differences in yield between Bossier, Improved Pelican, CES486-407 are not significant. All of them have a lower yield in the second (minor) season, but CES varieties have a longer vegetation period, and we have difficulties with seed quality. In comparison with Kent the yield of all of these varieties is about 6 to 15 percent higher, tested in two years at different locations.

NSOWAH: What spacing did you adapt when you were comparing yields of Kent and Improved Pelican, knowing that Kent is a dwarf variety?

PLARRE: We used a wide spacing of 75 cm between the rows and a distance of 4 cm within the rows. You are right, Kent gives higher yield in closer spacing. This was found out by our agronomist in conducting special trials. In the soybean breeding program we use only one conventional spacing. You also will find more details about spacing in the annual report I will send to you.

Soil Fertility and Inoculation in Soybean Production

S. Abu-Shakra

Soybean is a very important oil and protein crop. The soybean is an ancient crop plant that was extensively cultivated in China. It is considered as one of the five sacred grains essential to the survival of Chinese civilization, the other grains being rice, millet, wheat, and barley (3). The first written record of the soybean plant dates back to 2838 B.C. (24). This crop was introduced to the New World in the early nineteenth century. At present it is widely grown in the Western Hemisphere and particularly in the United States.

The soybean is a warm-season crop that has climatic requirements similar to those of corn. Although there are varieties that can grow in hot climates, very high temperatures are unfavorable to most varieties, especially under dry conditions. Temperatures below 18°C delay seed germination. Smith et al. (35) and Hartwig (14) found that the rate of germination and early plant growth increased markedly as temperature at planting time increased. The optimum temperature for flowering of all varieties is about 25°C. Temperatures above 38°C and below 10°C greatly reduce soybean growth (4). High temperature results in soybean seed that is low in oil and oil quality. Howell and Collins (17) found the levels of both linoleic and linolenic fatty acids to be inversely correlated with temperature.

The soybean is a short-day plant. All varieties flower in less than 30 days after emergence if exposed to daylight less than 12 hours. Varieties differ in their flowering response if the day length exceeds 12 hours (4). Varieties adapted to short-day requirements, which are found in tropical and subtropical areas, grow vegetatively under long days and flower very early under short-day conditions.

Soybeans can grow on all types of soil, but deep fertile loam with good drainage is most suitable for growth. Soybeans are sensitive to saline soils containing soluble salts above 7 mho/cm. Bernstein and Ogata (6) found that salinity greatly reduced nodulation of Lee soybean at 5.4 atm of added NaCl and that dry weight of formed nodules decreased significantly with the increase in salinity. Soils that are slightly acidic to neutral are most suited for optimum soybean growth. For best results it is recommended that acid soil should be limed to pH 6.0 to 6.5 (8).

The soybean plant is an erect, rather bushy annual. It has a main stem with a number of branches developing from the lower nodes. Depending on variety and environment, plant height may vary from 30 to more than 100 cm. It has purple or white flowers borne in racemes at the leaf axils. Most of the flowers abort and only about one-fourth to one-third of the total produce pods. The pods contain one to five seeds.

Soybeans have a deep tap-root system that develops numerous branches in the upper soil layer. Like other legumes, soybean roots develop nodules in the presence of the appropriate strain of *Rhizobium* bacteria. These nodules contain millions of bacteria which obtain their energy from the plant and in return supply the plant with nitrogen which they fix from the atmospheric elemental nitrogen.

Inoculation

Soybeans are a new crop to many agricultural areas in the world. Therefore, it is absolutely necessary that soybean seeds be inoculated with the appropriate strains of *R. japonicum* if the crop has not previously been grown in the same field. It is safer always to inoculate before sowing although it may be unnecessary if soybean has been grown in the same field one or two years previously. Abu-Shakra and Bassiri (1) found that soybeans grow in Lebanon on land planted the previous year with inoculated soybeans produced more nodules, lodging, seed yield, 1,000-seed weight, and protein content, and less seed oil percentage as compared to those grown on land planted with noninoculated soybeans. Seed yield from the previously inoculated field was 3,000 kg/ha compared to only 2,000 kg/ha from the field that was devoid of the specific strains of *R. japonicum*.

S. ABU-SHAKRA: Chairman, Department of Crop Production and Protection, American University of Beirut, Lebanon.

Inoculum is usually sold as a black powder (mixed in ground peat) in waterproof packages. Only fresh inoculum should be used and it should be stored in a cool place prior to use. However, inoculum should not be used after its expiration date even if it has been stored in a cool place. High temperatures, dry weather, and direct sunlight can kill the bacteria in a short time. Therefore, in dry weather, inoculated soybeans should be covered with a damp cloth before planting. It is always advisable to irrigate the field soon after sowing in dry soil. Purchasing the inoculum from foreign countries should be done by air mail. With imported inoculum it is advisable to use two to five times the recommended rate of inoculum specified on the package. Abu-Shakra and Bassiri (1) found that by using five times the recommended rate of inoculum the dry weight production of soybean nodules was doubled compared to that produced by using the recommended rate. Based on a thorough study of the literature, Purchase and Nutman (28) emphasized that root hair infection by the bacteria depends on density of the bacteria at the rhizosphere, and that the relationship between inoculum density and nodulation is linear up to a maximum point set by some limiting factor, such as the maximum population that can occupy the rhizosphere. In 1966 Stewart (36) reported an almost linear relationship between nodule and lateral root number per plant, and plants with strongly developed tap roots and few lateral roots nodulate less abundantly than do those with numerous fibrous roots.

Prior to application of the inoculum it is advisable to add a sticker solution to the seed. A sticker solution prepared by dissolving 25 g sugar in 100 ml water is recommended. When soybean seeds are treated with fungicides that are toxic to *Rhizobium*, the inoculum should be added to the treated seed immediately before planting. The treating of seeds with fungicides should be avoided if the seeds have a high germination capacity. Nodulation should be examined 2 to 3 weeks after seedling emergence. If nodule formation is found to be very poor, appropriate amounts of N fertilizers should be added to the soil to ensure good yield. The best time to evaluate nodulation is at the beginning of flowering stage and 1 to 2 weeks later. Effective nitrogen-fixing nodules are pink on the inside; ineffective nodules are white. Nodule formation in soybeans tends to concentrate below the crown region unless the bacteria were uniformly present in the soil; then nodules will be distributed over the surface of all roots in the upper soil layer.

Nodulation and N Fertilization

Nodulation and symbiotic N fixation are highly influenced by the N level present in the soil solution. In 1971, Abu-Shakra and Bassiri (1) found that N fertilization (120 kg N/ha) reduced the total number of nodules per plant. Similar results were reported by Beard and Knowles (4) from experiments done at Davis, California. Numerous soybean fertility experiments are reported in the literature. Only a few, however, contribute to understanding of the sensitive relationship between the level of soil N and the amount of N fixed symbiotically by *Rhizobium*. As early as 1864 Rautenberg and Kuhn (29) were the first to observe that ammonia and nitrate N inhibited nodulation of vetch in culture solutions. In 1924, Perkins (77) found 46, 60, 53, 10, and 0 nodules per 10 soybean plants with the application of 0, 57, 284, 568, and 1,135 kg sodium nitrate per hectare, respectively. In addition, Perkins's findings indicated some stimulation of nodulation by small applications of N fertilizers. Biobel (10) in 1926, Hopkins et al. (16) in 1932, and Richardson et al. (30) in 1957 reported a stimulation effect of small amounts of N fertilizers on nodule formation in different legumes. In 1959, using N^{15} in greenhouse experiments, Allos and Bartholomew (2) found that elemental N was fixed only when small amounts of combined N were present. They also found that combined N was used preferentially over symbiotically fixed N. Using nodulating and non-nodulating isolines, Sears and Lynch (33) in 1951 and Weber (37) in 1966 found that the amount of N symbiotically fixed depended mainly upon the availability of soil N. Nodule weight, number, and size and the amount of N symbiotically fixed were inversely related to increases in fertilizer N. In a gravel culture experiment, Harper (12) in 1974 found excellent nodulation at one-fourth concentration of a modified Hoagland nutrient solution, fair nodulation at one-half concentration, and no nodulation at high concentrations. The amount of N symbiotically fixed depending on availability of soil N and other soil conditions was reported by Weber (37) to range from about 1 to 160 kg/ha, which is equivalent to about 1 to 74 percent of the total N uptake by the plant, respectively. Hatfield et al. (15) in 1974 found that the addition of N (10 meq N/1 NO_3^- solution in a hydroponic culture experiment) for 2 weeks following seedling emergence increased the number of nodules. Their results provided evidence of the importance of soil N for the initiation of growth of soybeans even with adequate inoculation. Similar results were found by Harper (13) in 1974 who reported higher $N_2(C_2H_2)$fixation (using the acetylene reduction assay) by plants grown on

low nitrate compared to those grown on no nitrate. He also found that seed yield of plants grown on high nitrate levels, which inhibited symbiotic N-fixation, was less than the yield of plants using both nitrate and fixed atmospheric N. These findings indicate that for maximum yield in soybeans symbiotic N fixation and soil N utilization are both essential. Early in 1974, Lawn and Brun (18) reported that symbiotic N fixation, using the acetylene reduction assay, increased during the flowering period, reaching maximum near the end of flowering and then declining markedly during the early pod filling stage. In another study they added supplemental N as ammonium nitrate at the end of flowering to Chippewa 64 and Clay varieties. Seed protein was increased in both varieties but seed yield was increased only in the Clay soybean (19). More work is needed to determine the best time to apply supplemental N to maximize yield.

In a current experiment on the effect of inoculation and fertilization with N and minor elements on nodulation and soybean production, the author found a significant effect of N fertilization and minor elements on nodulation (Table 1). Low N (50 kg N/ha) produced significantly more weight of nodules than was produced in treatments that received more N. The addition of high amounts of N resulted in a significant reduction in nodulation. Iron application has also resulted in increased nodulation. The influence of minor elements on nodulation is being further investigated.

Table 1. Nodulation (g/10 plants) in soybeans as influenced by nitrogen fertilization and foliar sprays of iron, manganese, and zinc.

Nitrogen[a/] (kg/ha)	Foliar Sprays[b/] Fe	Mn	Fe+Zn+Mn	Fe+Mn	Mean[c/]
50	2.942	2.622	2.191	1.974	2.432(a)
50+80	2.585	2.134	1.879	1.551	2.037(b)
50+160	1.825	1.378	1.598	1.052	1.463(c)
50+80+80	1.429	1.225	1.209	1.226	1.282(c)
Mean	2.195(a)	1.865(b)	1.719(b)	1.461(b)	

[a/] 50 kg N/ha was applied to all treatments before sowing. The first additional application was made when plants were 25 cm high and the second when plants were 75 cm.

[b/] Fe was applied four times (1 kg $FeSO_4$/ha each time), Zn was applied twice (1 kg $ZnSO_4$/ha each time) and Mn was applied twice (0.6 kg $MnSO_4$/ha each time). Combinations of Fe + Zn + Mn and Fe + Mn were applied twice using the rates mentioned above.

[c/] Means followed by the same letter are not significantly different from each other at the 1 percent level.

Phosphorus and Potassium

The author did no work on the effect of phosphorus and potassium on soybean production in the soils of Lebanon.

The soil in Lebanon is calcareous, low in P but high in available K with a pH of about 8. However, P and K uptake has been reported in Iowa soils to be 19 and 90 kg/ha, respectively. The seeds contained 14 kg of P and 45 kg of K (11). Beard and Knowles (4) reported that soybeans responded to the application of P when the soils contained less than 50 kg available P/ha. Any extra amount of P added to the soil is not lost because it is reserved for succeeding crops. Soils low in P definitely should be fertilized with P. It is recommended to add K and P when soil tests show less than 300 kg available K/ha and less than 100 kg P/ha. A 3,000 kg/ha soybean crop removes about 115 kg/ha K in the seed, which corresponds to about 60 percent of the total K absorbed by the crop (31).

Other Nutrients

Soybeans require other nutrients such as calcium, magnesium, sulfur, manganese, iron, molybdenum, zinc, boron, and copper. However, most of these elements are not commonly deficient in soils. Lucas and Knezek (22) extensively reviewed the literature for the effect of climate and soil conditions on micronutrient deficiencies in plants. They reported high response of soybeans to Fe and Mn, medium response to Zn and Mb, and no response to Cu and B under soil conditions favorable for their deficiency. The soils of Lebanon tend to be deficient in Fe, Mn, and Zn, but not in Mb. Being calcareous, they are high in Ca.

Lucas and Davis (21) observed that the optimum pH for most plants is about 6 to 6.8; in this range Fe, Mn, and Zn were found to be neither excessive nor deficient. The deficiency of these elements is more frequent in alkali soils. Murphy and Walsh (25) reported that most of the field crops, including soybeans, suffered from Fe deficiency and responded to Fe application. When deficiency is observed, correction measures must be undertaken if acceptable yields are to be maintained.

Slack (34) reported that it is the ferrous form of Fe that is metabolically active and plants containing large amounts of ferric Fe show deficiency symptoms. Morachan et al. (23) and Brown and Tiffin (7) observed Fe chlorosis with increased P_2O_5 application. Lingle et al. (20) stated that excess Zn reduced the translocation of Fe in soybeans and reduced the root absorption. Franco and Dobereiner (9) found that high soil Mn content had an immediate toxic effect on soybean yield and nodule formation. Berger (5) reported that Mn toxicity appears in strongly acid soils and Mn deficiency appears in alkaline soils.

Rossi and Beauchamp (32) reported that ZnCl was more highly absorbed than $ZnSO_4$ and Zn absorption was favored with relatively high relative humidity. Rogers et al. (31) found that response to Mb was obtained only on a very acid soil. No response to Mb was obtained when the soil was limed. In general, the correction of microelements by spray applications is more advisable than by soil application.

General View of Nutrient Uptake

During germination and for about one week after emergency, the cotyledons are the main nutrient source for nourishing the young soybean seedling. A high concentration of fertilizers placed in a band about 3 cm to the side and below the seed accelerate the rate of growth at the early stage of vegetative development. However, placement of fertilizers too close to or with the seed can cause injury to the young plant.

The accumulation and redistribution of mineral nutrients were extensively reviewed by Ohlrogge (26). Harper in 1971 (12) studied mineral uptake and accumulation in soybeans during the different stages of development. The uptake of N, P, K, Ca, and Mg was found to be low during the first 30 days after emergence. The rate of nutrient uptake increased at initial flowering and reached its peak between full bloom and midpod fill. N, P, and K uptake declined through later stages of development. The concentration in the tops of Fe, Mn, Zn, Cu, and B was generally reduced from the seedling stage through maturity. Under high fertility, plants tend to take up a greater quantity of nutrients than required for their immediate needs. These nutrients are stored in older tissues to be redistributed to needed sites in the plant during plant growth. At maturity, soybean seeds contain about 75 percent of the N and P and about 60 percent of the K taken up by the plant (11).

Table 2. Guideline information on content of nitrogen, phosphorus, and potassium in soybean seeds in comparison to the whole plant, and efficiency of soybeans in absorbing these elements from the soil.

Element	Percent content in seed	Percent content in seed compared to plant	Percent uptake efficiency from soil
N	6.5	75	60
P	0.9	75	20
K	1.6	60	50

The amounts of fertilizers required to be added to a soybean crop can be estimated after performing a soil test for N, P, and K and after determining the soil pH and the availability of other essential elements for soybeans. Knowing that the amounts of fertilizers to be added to a soybean crop are determined by the projected seed yields, one can utilize the information summarized in Table 2 to calculate the quantities of N, P, and K fertilizers needed.

REFERENCES

1. Abu-Shakra, S., and A. Bassiri. 1972. Effect of inoculation and nitrogen fertilization on nodulation, seed yield and quality of soybeans. J. Agr. Sci. Camb. 78:179-182.

2. Allos, H.F., and W.V. Bartholomew. 1959. Replacement of symbiotic fixation by available nitrogen. Soil Sci. 87:61-66.

3. Aykroyd, W.R., and J. Doughty. 1964. Legumes in human nutrition. FAO Nutr. Stud. Rome 19.

4. Beard, B.H., and P.F. Knowles, eds. 1973. Soybean research in California. Calif. Agr. Exp. Sta. Bull. 862.

5. Berger, K.C. 1972. Sun, soil and survival. University of Oklahoma Press, Norman.

6. Bernstein, L., and G. Ogata. 1966. Effects of salinity on nodulation, nitrogen fixation, and growth of soybeans and alfalfa. Agron. J. 58:201-203.

7. Brown, J.C., and L.O. Tiffin. 1960. Iron chlorosis in soybean as related to the genotype of rootstocks: a relationship between susceptibility to chlorosis and capacity to absorb Fe from Fe chelate. Soil and Fert. Abstr. 23:354.

8. Cartter, J.L., and E.E. Hartwig. 1962. The management of soybeans. Adv. Agron. 14:359-412.

9. Franco, A.A., and J. Dobereiner. 1971. Manganese toxicity of an acid soil and soybean *Rhizobium* symbiosis. Pesquisa Agropecoria Brazileiria Agronomia 6:57-66.

10. Giobel, G. 1926. The relation of the soil nitrogen to nodule development and fixation of nitrogen by certain legumes. Pages 48-118 in Encyclopedia of plant physiology. Vol. 8. W. Ruhland, ed. 1926. Springer-Verlag (Berlin). And in E.K. Allen and O.N. Allen. 1958. Biological aspects of symbiotic nitrogen fixation. New Jersey Agr. Exp. Sta. Bull. 436.

11. Hanaway, J.J., and H.E. Thompson. 1967. How a soybean plant develops. Iowa State University Agr. Ext. Ser. Spec. Rpt. 53.

12. Harper, J.E. 1971. Seasonal nutrient uptake and accumulation patterns in soybeans. Crop Sci. 11:347-350.

13. Harper, J.E. 1974. Soil and symbiotic nitrogen requirements for optimum soybean production. Agron. J. 14:255-260.

14. Hartwig, E.E. 1954. U.S. Dept. Agr. Circ. 943 in J.L. Cartter and E.E. Hartwig. 1962. The management of soybeans. Adv. Agron. 14:359-412.

15. Hatfield, J.L., D.B. Egli, J.E. Legget, and D.E. Peaslee. 1974. Effect of applied nitrogen on the nodulation and early growth of soybeans (*Glycine max* L.Merr.) Agron. J. 66:112-114.

16. Hopkins, E.W., P.W. Wilson, and W.H. Peterson. 1932. Influence of potassium nitrate on nodule formation and nitrogen fixation by clover. Plant Physiol. 7:597-611.

17. Howell, R.W., and F.I. Collins. 1957. Factors affecting linolenic and linoleic acid content of soybean oil. Agron. J. 49:593-597.

18. Lawn, R.J., and W.A. Brun. 1974a. Symbiotic nitrogen fixation in soybeans. I. Effect of photosynthetic source-sink manipulations. Crop Sci. 14:11-16.

19. Lawn, R.J., and W.A. Brun. 1974b. Symbiotic nitrogen fixation. III. Effect of supplemental nitrogen and intervarietal grafting. Crop Sci. 14:22-25.

20. Lingle, J.C., L.O. Tiffin, and J.C. Brown. 1963. Iron uptake transport of soybeans as influenced by other cations. Plant Physiol. 38:71-76.

21. Lucas, R.E., and J.F. Davis. 1961. Relationship between pH values of organic soils and availability of twelve plant nutrients. Soil Sci. 92:117-182.

22. Lucas, R.E., and B.D. Knezek. 1972. Climatic and soil conditions promoting micronutrient deficiencies in plants. Pages 265-288 in J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay, eds. Micronutrients in agriculture. Soil Science Society of America, Inc., Madison, Wis.

23. Morachan, J.B., G. Kesavani, and M. Madanam. 1971. Iron chlorosis in soybean and maize. Madras Agri. J. (India) 58(1):20-25.

24. Morse, W.H., and J.L. Cartter. 1937. Improvement in soybeans. Pages 1154-1189 in U.S. Dept. Agr. Yearbook 1937.

25. Murphy, L.S., and L.M. Walsh. 1972. Correction of micronutrient deficiencies with fertilizers. Pages 351-352 in J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay eds. 1972. Micronutrients in agriculture. Soil Science Society of America, Inc. Madison, Wis.

26. Ohlrogge, A.J. 1960. Mineral nutrition of soybeans. Adv. Agron. 12:229-263.

27. Perkins, A.T. 1924. The effect of several mineral fertilizers upon nodulation of Virginia soybeans. Soil Sci. 17:439-447.

28. Purchase, H.E., and P.S. Nutman. 1957. Studies on the physiology of nodule formation. VI. The influence of bacterial numbers in the rhizosphere on nodule initiation. Ann. Bot. N.S. 21:439-454.

29. Rautenberg, F., and G. Kuhn. 1864. Vegetationsversuche in sommer 1863. Landw. Vers.-Sta. 6:355-359. In E.W. Hopkins, P.W. Wilson, and W.H. Peterson. 1932. Influence of potassium nitrate on nodule formation and nitrogen fixation by clover. Plant Physiol. 7:597-611.

30. Richardson, D.A., D.C. Jordan, and E.H. Garrard. 1957. The influence of combined nitrogen on nodulation and nitrogen fixation by *Rhizobium meliloti* Dangeard. Can. J. Plant Sci. 37:205-214.

31. Rogers, H.T., D.L. Thurlow, F. Adams, C.E. Evans, and J.I. Wear. 1971. Soybean production--fertility requirements. Auburn University Agr. Expt. Sta. Bull. 413.

32. Rossi, N., and E.G. Beauchamp. 1971. Influence of relative humidity and associated anion on the absorption of Mn and Zn by soybean leaves. Agron. J. 63:860-863.

33. Sears, O.H., and D.L. Lynch. 1951. Importance of inoculation. Soybean Dig. 11:15-16.

34. Slack, A.V. 1967. Page 5 in A.V. Slack, Chemistry and technology of fertilizers. John Wiley and Sons, New York.

35. Smith, T.J., H.M. Camper, M.T. Carter, G.D. Jones, and M.W. Alexander. 1961. Virginia Agr. Expt. Sta. Bull. 528. In J.L. Cartter and E.E. Hartwig. 1962. The management of soybeans. Adv. Agron. 14:359-412.

36. Stewart, W.P. 1966. Nitrogen fixation in plants. Athlone Press, University of London.

37. Weber, C.R. 1966. Nodulating and nonnodulating soybean isolines. II. Response to applied nitrogen and modified soil conditions. Agron. J. 58:46-49.

DISCUSSION

S.D. AGBOOLA: In temperate legumes it is possible for adequate nodulation to supply all the nitrogen needed. In Nigeria we have found that for *Vigna*, symbiotic N is not enough. In *Centrosema* and some other pasture legumes, it is also not enough. You have just said that the same is true for soybean. Would you say that this condition is general for tropical legumes?

S. ABU-SHAKRA: I don't like to generalize on this for all legumes. Here again it depends on how good the nodulation is and how high the yields you expect to get. Additional N fertilization seems to be needed for maximum potential yields of soybeans. The economics of crop management must enter into the picture.

AGBOOLA: You have mentioned some requirements for a successful seed inoculation. To my mind the method of inoculation will depend on the seed you want to inoculate. Take some soybean varieties which carry their testa above soil with the cotyledons when they germinate. If this happens you lose your inoculum. In such a case a wafer suspension inoculum might answer. On the basis of the purely theoretical supposition, it is valid to assume that the more concentrated (number of *Rhizobium* cells per ml of inoculum) the suspension, the better are the chances of successful inoculation, irrespective of the death rate of the organisms after introduction into the soil. Soil inoculation is useful especially in countries where there is no commercial production of inoculum. Have you tried soil inoculations and with what results? For how long can you keep a peat-based inoculum and still maintain its effectiveness or viability.

ABU-SHAKRA: First you don't have to add a sticker solution to glue the bacteria to the seed. All you need is to have a sticker solution which is strong enough, to make sure that enough of the inoculum sticks to the seed.

V.M. BHAN: If irrigation should be given after planting soybean then rust would be the major problem in some soils.

ABU-SHAKRA: The important thing is the soil moisture level. If it can be achieved by pre-irrigation planting to avoid forming a crust then this will be suitable for seed germination and the *Rhizobium* bacteria. The point is not to leave the bacteria long in a dry soil.

BHAN: Have the nonnodulating lines of soybean been grown to work out the nitrogen requirements?

ABU-SHAKRA: It has not been done. The values are based on relative performance under different levels of nitrogen and inoculation of the nodulating lines.

AGBOOLA: We assume that commercial *Rhizobium* strains have been selected not only for effectiveness, but also for persistence and competitiveness. What is your experience with these strains, especially with different soil types?

ABU-SHAKRA: We kept records for the survival of the bacteria in the soil only for one year. We did not study the effect of different soil types on its survival and nodulation effectiveness.

AGBOOLA: Have you noticed any apparent lateral movement of introduced *Rhizobia* into adjacent uninoculated fields, say after some years of inoculation? If so what is responsible?

ABU-SHAKRA: This condition was not studied either. Natural movement of the bacteria in soils is a very slow process. But the transport of bacteria from one field to another can take place by run-off and mechanical means.

T.I. ASHAYE: The levels of micronutrients in the soil and their requirement by soybeans were not mentioned. Is this deliberate? The same approach was given to the treatment of nitrogen. What in fact do N_1, N_2 etc. mean in terms of concentration?

Finally, I feel that it is essential to determine the level of the nutrients actually present in the soils for effective fertilizer programs.

ABU-SHAKRA: It is important to know the fertility level of your soil for both macro- and micro-elements. Also the response of soybeans to these different elements. If you know all this, and if you also know the yields you expect to get or the yields you would like to obtain, then by referring to the information I mentioned before regarding the content of these elements in the seed, etc.--you can easily calculate the approximate amounts of fertilizers your soybean crop would require.

Water Management for Soybeans

R.K. Jana

In traditional agriculture the farmer is dependent upon nature for his water supply, which usually ranges from extreme deficiency to extreme excess, often within the same season. In this setting, the farmer uses traditional management practices and his yields are often low and his products unstable. In scientific agricultural production, however, the farmer must consider water as a "manageable" input. The recent introduction of scientific agricultural practices, such as the use of high-yielding varieties and fertilizer application, has sharply focused attention on the need for improved water management (8).

Water management is often equated with irrigation. Water management includes irrigation, but it must be considered in a much broader context. Water management begins when it falls as rain or snow and continues until it is efficiently used by the growing plant. The fundamental requirement in water management practice is to balance between the supply of water and the use of water in a way to obtain maximum agricultural production. For this it is necessary to know how much water is available to what depth in the soil profile, how the moisture in the rooting zone is released with the evapotranspiration demand of the crop, and whether the water supply equals or exceeds crop demand during each period of the growing season. Normally, in the rainy season the rainfall exceeds the crop demand. The result is an excess of moisture during that period and moisture deficit during the remainder of the year. As rainfall is quite uncertain and erratic, crops may suffer due to lack of water even during the monsoon season. When the amount of available water from incident rainfall that can be stored in the root zone is insufficient, additional water in the form of irrigation is required.

The readily available soil water for plant growth is taken as the amount of water retained in a soil between field capacity and the permanent wilting percentage. Since field capacity represents the upper limit of soil water availability and the permanent wilting percentage a lower limit, this range has considerable significance in determining the agricultural value of soils. It is now generally accepted that water between field capacity and permanent wilting point is not equally available for growth. Crop growth and transpiration generally decrease as the wilting point is approached. Factors such as distribution and depth of the root system, conductivity of the soil for water, crop characteristics, and low or high evaporative demand, all influence the point at which growth or transpiration of a plant is retarded due to the lack of soil water.

There are certain critical stages in the growth cycle of crops. If the crop experiences water deficit at these stages, it receives a physiological setback which may cause a serious reduction in yield and sharply lowers water use efficiency even though the total seasonal water use is only slightly reduced. Knowledge of such critical stages is particularly important for areas where the water supply is limited. Under such situations, selective application of irrigation only at the critical stages results in the highest return from a unit volume of water applied.

Water is often the primary limiting factor in soybean production and this is an important management concern. A high-yielding crop of soybeans (3,360 kg/ha) would need 625 cm (25 inches) of water during the late growing season (10). Whitt and van Bavel (19) reported daily water use of soybeans to be as much as 0.75 cm. Thus, in areas of low rainfall, irrigation is a necessary and often profitable practice. In humid areas irrigation has seldom been profitable unless practiced on sandy soils. This may be due to two inherent characteristics of the soybean plant--an extensive root system and a relatively long flowering period. While the rooting characteristics depend on the physical characteristics of the soil and moisture conditions, the roots are extensive, both horizontally and vertically, on many silt loam soils (8, 11, 20). Some roots extend horizontally at very shallow depth (5 to 10 cm) into the inter-row area and then turn downward and reach depths of 150 cm. Thus, the rooting habit of this plant in many soils allows it to extract water exceedingly well (9).

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The long flowering period enables the soybean plant to escape or survive short periods of drought stress. Failure of early flowers to set pods due to water stress may be compensated for by excellent pod set of late flowers if moisture becomes available. A shortage of moisture during the pod-filling stage reduces yields more than during the flowering stage (13, 14, 18). Therefore, if limited water is available for irrigation, application during the pod-filling stage will prove most beneficial (12, 16).

Water is a basic input influencing crop production. Both deficit as well as excess moisture reduces the crop yields drastically. Various surveys have highlighted the fact that the farmers are greatly concerned about the timely availability of their irrigation water so that they can apply it when needed. Thus, if a farmer has a dependable system for removing excess water and applying water when needed, he will invest in the other necessary inputs for improved agricultural production.

This paper reports the results of a set of experiments aimed at solving a specific water management problem of Madhya Pradesh, India. In the experiments, soybeans were used as one of the test crops.

WATER MANAGEMENT PROBLEMS IN MADHYA PRADESH, INDIA

In central and eastern Madhya Pradesh (lat. 23°N) there are extensive areas of fine-textured heavy black soils (Vertisols) which are not effectively used during the rainy season because of difficulties in land preparation, timely planting, and poor crop performance caused by imperfect surface drainage. It is a common practice to fallow the crop land in the monsoon season rather than to grow a kharif (monsoon) crop. Cultivators avoid cropping mainly for three reasons: (a) the difficulty in working with the soil in early monsoon in preparation for planting the kharif crop; (b) the relatively low yields due to damage caused by temporary flooding of kharif crops during heavy monsoon rains; and (c) the possibility that the kharif crop will extract too much soil moisture reservoir in the profile to the detriment of the rabi (post monsoon) crop.

Further, in these areas, 85 percent of the 55-inch average annual rainfall is received during the July to September monsoon season. To overcome these problems, which are often acute from the viewpoint of agricultural production, it is highly desirable to conserve some or all of the excess monsoon rainfall in a way that permits its use as needed during the kharif and rabi seasons.

The soil is a deep Vertisol, commonly known as "black cotton soil," having a rather uniform clay content of 45 to 50 percent throughout the first meter of the profile. Bulk density increases from the surface to 40 cm depth (1.3 to 1.6 g/cm^3), remaining almost constant (1.6 to 1.7 g/cm^3). The one-third and 15-atmosphere moisture percentage of undisturbed samples from the surface 30 cm, expressed on a volume basis, are 40 and 18 percent respectively. This soil has a high coefficient of expansion and contraction on wetting and drying. When wet it becomes extremely sticky and is difficult to work with. When dry it becomes very hard. The upper and lower plastic limits of this soil are around 48 and 22 percent respectively, giving a plasticity number of 26.

Since 85 percent of rainfall occurs during the monsoon season it would seem logical to grow a crop during the monsoon season with proper water management practices. However, an improvement of surface water removal by land shaping and ridging or bedding of the soil surface could help to grow kharif crops such as maize, sorghum, and soybeans. The run-off water could be collected, stored, and pumped back as a supplemental irrigation whenever the crops need it. There is insufficient information available to show the amount of run-off water that can be expected for a given slope under a particular rainfall distribution. Accordingly it was decided to collect such data under Jabalpur conditions.

WATER HARVEST AND SURFACE DRAINAGE EXPERIMENT

A field experiment was conducted on the livestock farm of Jawaharlal Nehru Agricultural University at Jabalpur with the following objectives:

1. To determine how much run-off occurs in a given precipitation from row crops growing on plots with a uniform slope of 0.75 percent.
2. To see how much of this run-off water is required by a kharif paddy crop to supplement the natural precipitation.

3. To determine the soil moisture profile throughout the kharif season under maize and soybeans.

4. To determine whether the stored kharif run-off (harvested water) is sufficient to recharge the soil profile following the kharif crop and to meet the water needs of a rabi crop of wheat and other crops grown on the run-off producing area.

The total area of the experiment was about one acre. The area was ploughed, disked, and shaped a little through topographic survey so as to have a slope of 0.75 percent in the east-west direction (Fig. 1). The field was divided into six strips 200' x 35' each along the slope. Each strip was again subdivided into 150' x 35' upper and 50' x 35' lower subplots. A 10 ft border was left between the strips. The upper 150' x 35' subplots were used for growing row crops of maize and soybeans, while paddy was grown in the smaller 50' x 35' subplot located at the lower end of the slope. At the boundary between the subplots a 35' x 9" x ½" wooden plank was installed to check erosion of the border soil and to demarcate the boundary between the upper and lower subplots.

Below each strip a 25' x 20' x 2' reservoir was constructed for collecting and measuring the run-off water from each of the six plots. At the center of the reservoir another small 3' x 2' x ½' pit was dug which served as a sump for the pump used to remove the water from the reservoir (Fig. 2). By growing paddy in the lower subplot it was possible also to use the area for storage of some of the run-off from the area above it, thus supplementing the storage capacity of the reservoir during periods of continuous rain.

Maize and soybeans were planted in rows parallel with the slope in the upper subplots. Paddy was direct-seeded in rows across the slope in the lower subplots. All the other agronomic practices were followed at the optimum levels.

The volume of run-off water collected in each reservoir was measured by noting the elevation of the water surface on a wooden graduated gauge stake installed at a distance of 2 ft from the edge of each reservoir. To calibrate the gauge stake, each reservoir was pumped out through a water meter, and volume of water per centimeter of subsidence on the gauge stake was recorded. In this way the relation of the depth in the tank to the quantity of water was determined and subsequent run-off volumes were determined from the gauge stake readings. Whenever the reservoirs were more than half-filled they were emptied by use of a high-volume low-lift pump.

A tractor-mounted hydraulic core sampler was used to obtain reliable values of soil moisture and bulk density for the determination of moisture data on a volumetric basis. The power core sampler was used to take undisturbed soil samples to a depth of 200 cm. The core sampler can be driven directly into the soil by the hydraulic cylinder driven by the power transmitted from the pump connected to the tractor. The sampler takes an undisturbed cylindrical core of soil which is then transferred in a specially fabricated holder to the laboratory for measurement of bulk density and moisture content (6). Data on rainfall and open pan evaporation were taken from the records of the meteorological observatory at the farm about one-half mile from the site of the run-off plots. The evaporation was measured from a standard U.S. Department of Agriculture open pan evaporimeter. The experiment was conducted in the 1970 rainy season and repeated in the 1971 rainy season.

Results and Discussion

Grain yields of soybean, maize, and rice (paddy) from the 1970 and 1971 experiments are presented in Table 1. The growth and yields of soybeans and maize were striking in the area during monsoon season. However, yields of soybeans were significantly higher compared to maize in both years, suggesting that soybeans are tolerant to excess moisture (15). The surface drainage provided through slopes were not enough for maize, whereas under the same drainage condition soybeans grew well. However, rice yield was good under the condition, which was semi-upland. Since rice grows well under lowland conditions, the purpose of growing rice in the experiment at the lowest elevation was to arrest the eroded soil particles while run-off water was passing through the rice growing area. Further, at the lowest elevation removal of excess water through surface drainage would be very slow; rather, soils would be saturated or sometimes flooded, where soybeans or maize cannot survive.

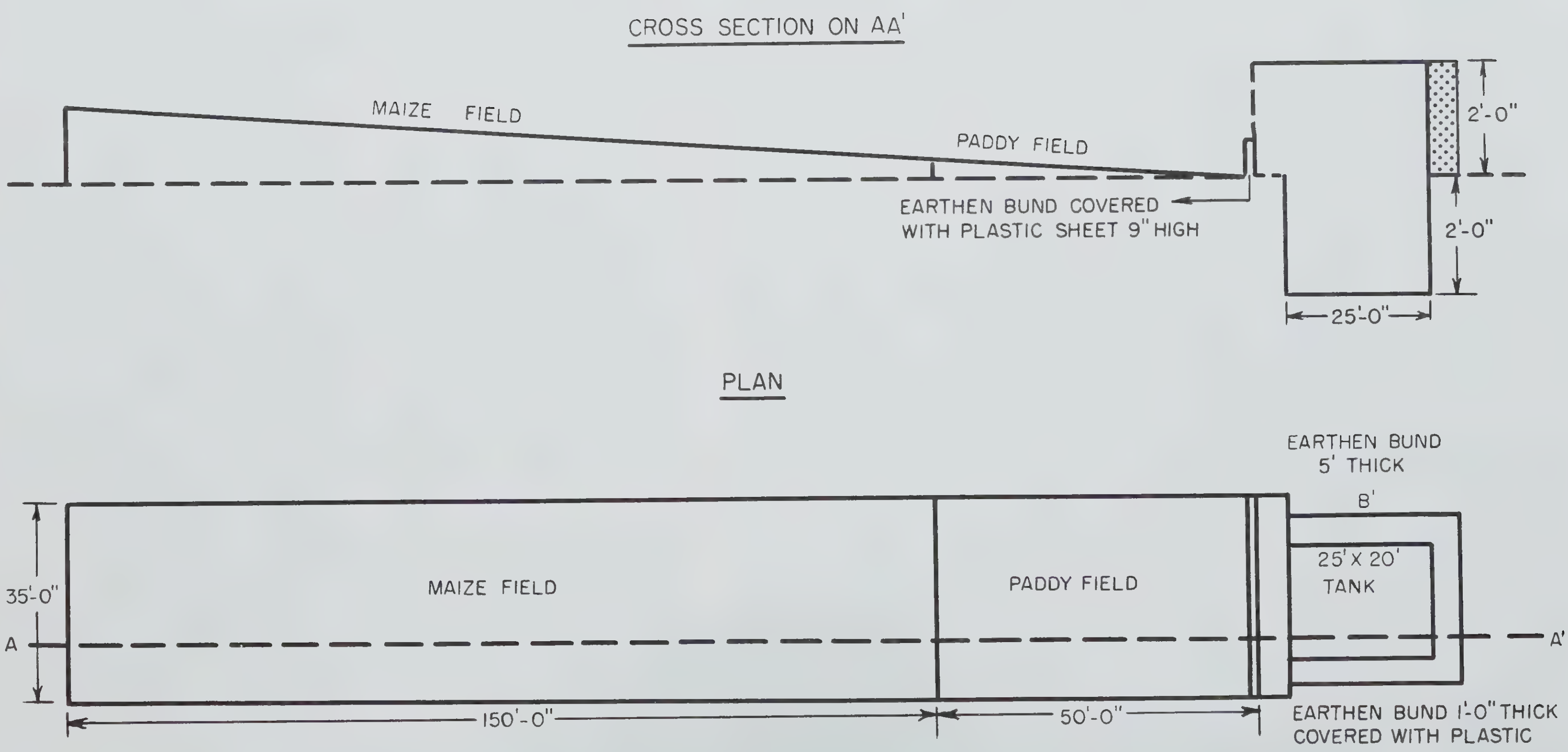

Fig. 1. Plan of fields used in water harvest and surface drainage experiment.

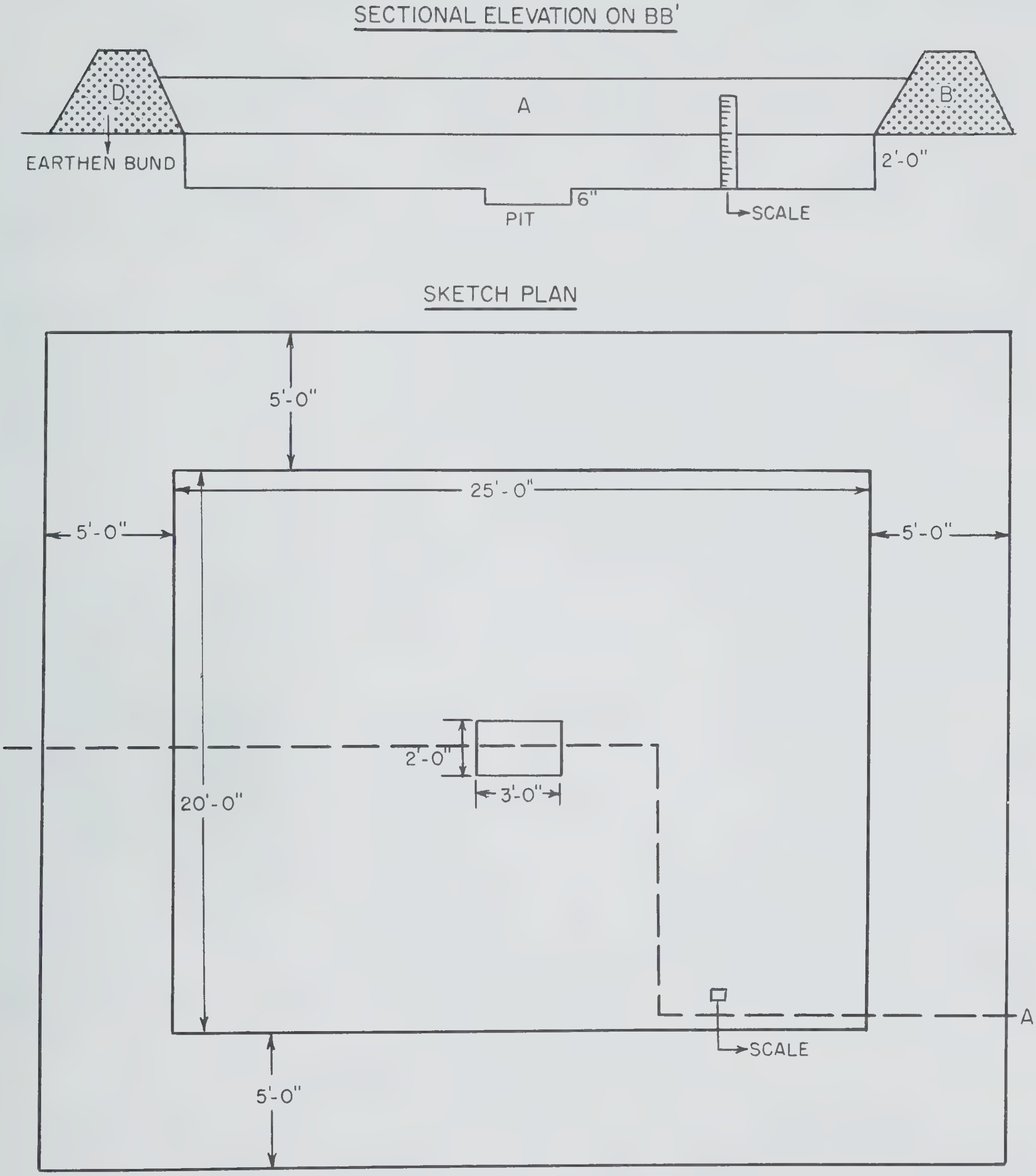

Fig. 2. Plan of reservoir for collecting and measuring run-off water.

Table 1. Yield of different crops grown during kharif (monsoon season) on run-off plots.

Crop	1970 season		1971 season	
	Grain (q/ha)	Stalk (q/ha)	Grain (q/ha)	Stalk (q/ha)
Maize	21.20	86.30	10.85	84.77
Soybean	28.12	28.01	35.00	52.50
Paddy	39.40	62.90	36.40	89.67

In the 1970 experiment there was a run-off of 43, 30, 74, and 74 percent from maize and 40, 24, 65, and 60 percent from soybeans during the months of June, July, August, and September, respectively, with a rainfall of 8.6, 18.1, 51.6, and 27.4 cm respectively. Thus with a total of 105.7 cm of rainfall during the entire period of study, 64 percent of this appeared as run-off from the maize crop and 54 percent from soybeans (Table 2). In the 1971 experiment with a total rainfall of 101.9 cm during the entire period of study, 69 percent of this appeared as run-off from the maize crop and 64 percent from soybeans (Table 2). Thus run-off obtained from maize was higher than that of soybeans. This was primarily due to variation in plant canopy and growth habits of maize and soybeans.

Besides measuring run-off the moisture content of the soil was measured at a number of points in the plot to determine the amount of water stored in the profile or to determine the moisture depletion pattern by soybeans and maize crops during different growth stages. In the 1970 experiment the moisture content was also determined in the surface and subsurface soil layers on July 28, i.e., before usable run-off occurred. The moisture content of surface and subsurface soils under maize was 20.4 and 21.4 percent and under soybeans 18.9 and 20.2 percent, respectively. The moisture depletion pattern at the beginning under maize and soybeans was not significantly different.

The moisture content of the soils at maturity of maize was significantly higher than that of soybeans (Table 3) at all depths indicating that soybeans utilized more moisture than maize (Fig. 3). However, under both crops moisture content consistently increased with depth. In the 1971 experiment a more detailed study of the moisture depletion pattern was made. Sampling was done on four different dates, covering the entire growth period of maize and soybean, at every 10 cm soil layers to a depth of 80 cm (5). Here again, moisture utilization by soybeans was significantly higher than maize. These data indicate that soybeans need more moisture for growth compared to maize in a given set of conditions.

In the 1970 experiment the net run-off available for future use was obtained in the months of August and September only. Thus, total run-off water of 40.1 cm was potentially available for use by the rabi crop when the maize crop was grown in kharif, and 31.2 cm of run-off water when soybean was grown. In the 1971 experiment, water harvested from maize was 54.8 cm and from soybeans 49.8 cm (Table 3). From this harvested water, 10 cm of water was irrigated back to meet the late-season water requirements of rice.

HARVESTED WATER UTILIZATION EXPERIMENT

After harvest of maize and soybeans, attempts were made to grow rabi crops on the run-off plots with a view to utilizing the harvested water. Each run-off plot was divided into four strips along the slope. Wheat, triticale, sunflower, and safflower were grown as a row crop in each strip. These were essentially grown under unirrigated conditions except for one "come-up" irrigation of 5 cm depth, given from the harvested water for good stand establishment which is necessary for good yield. Profile moisture use data were collected through the soil sampling technique described earlier. Soil sampling to a depth of 200 cm was done at the time of planting and again at harvest. Effective rainfall and amount of come-up irrigation were recorded. Moisture use data were computed on a volumetric basis. Reliable bulk density data were available through undisturbed soil sampling. By a simple bookkeeping method, moisture use by each crop was calculated.

Table 2. Rainfall, run-off, open pan evaporation Jabalpur, India.

Month	Rainfall (cm)	Run-off, maize plot (cm)	Percentage of total month's rainfall	Run-off, soybean plot (cm)	Percentage of total month's rainfall (cm)	Evaporation (cm)	Net run-off available for later use from maize	Net run-off available for later use from soybeans
				Rainfall June 16 to September 30, 1970 (cm)				
June	8.6	3.7	43	3.5	40	7.4	0	0
July	18.1	5.5	30	4.4	24	10.9	0	0
August	51.6	38.3	74	33.3	65	9.5	28.8	23.8
September	27.4	20.3	74	16.4	60	9.0	11.3	7.4
Total	105.7	67.8	64	57.6	54	36.8	40.1	31.2
				Rainfall June through October, 1971 (cm)				
July	57.7	49.2	85	45.1	78	4.9	44.3	40.2
August	30.0	17.4	58	16.5	55	6.9	10.5	9.6
September	14.2	4.3	30	4.6	32	8.0	0	0
Total	101.9	70.9	69	66.2	64	19.8	54.8	49.8

Table 3. Soil moisture depletion pattern as a function of depth under maize and soybean (percentage moisture by weight).

1970 Season, October 6[a]			1971 SEASON								
				Under maize				Under soybean			
Depth (cm)	Under maize	Under soybean	Depth (cm)	Sept. 25	Oct. 4	Oct. 27	Nov. 20	Sept. 25	Oct. 4	Oct. 27	Nov. 20
0-15	14.1	10.5	0-10	25.10	24.06	25.80	19.29	22.21	17.07	23.31	20.14
15-30	16.3	11.7	10-20	24.23	22.51	24.20	19.75	22.56	18.70	23.26	21.37
30-45	17.2	12.9	20-30	24.38	22.05	22.35	21.14	20.99	19.90	22.13	21.25
45-60	19.5	15.0	30-40	23.97	20.57	22.58	20.51	22.66	22.61	22.77	21.64
60-75	21.0	16.7	40-50	24.23	21.44	22.56	21.88	21.76	21.59	23.05	22.31
75-90	20.6	18.5	50-60	25.24	20.20	22.48	20.04	23.60	21.67	22.78	22.23
			60-70	--	--	--	20.02	--	--	--	21.44
			70-80	--	--	--	20.36	--	--	--	23.41

[a] Bhargava, O.M., 1971.

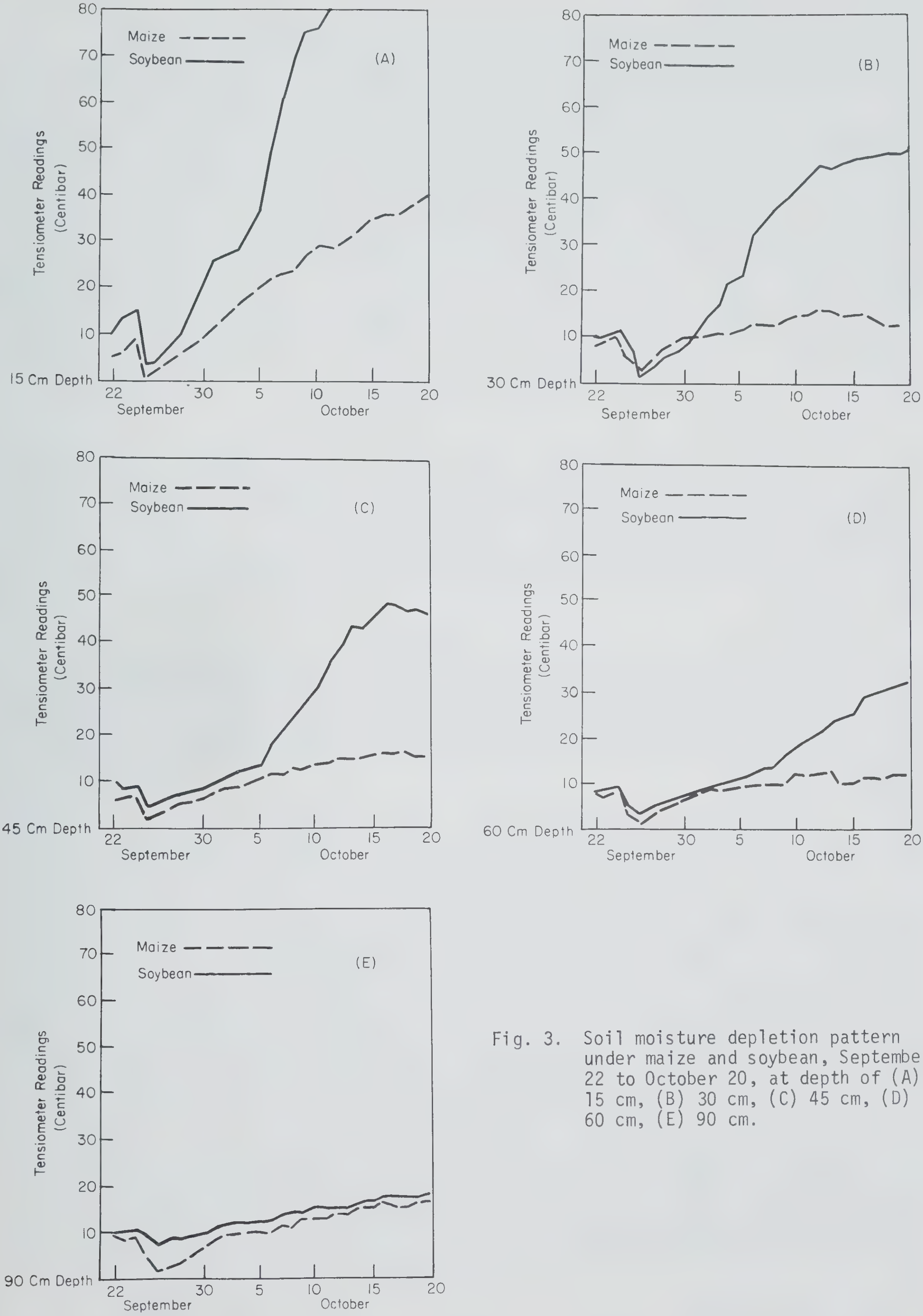

Fig. 3. Soil moisture depletion pattern under maize and soybean, September 22 to October 20, at depth of (A) 15 cm, (B) 30 cm, (C) 45 cm, (D) 60 cm, (E) 90 cm.

Results and Discussion

Results of yields and water use by each crop of wheat, triticale, sunflower, and safflower are presented in Table 5. The open pan evaporation during the experiment was 53 cm. It is interesting to note that up to a depth of one meter the profile water use was almost the same for all crops within a range of 12.4 to 14.7 cm. In the second meter depth there was significant difference in the profile water use pattern. Sunflower and safflower used almost double the amount of water used by wheat and triticale. This difference in water use pattern in the second meter depth is primarily due to rooting habit of the crops. The grain yield of wheat was 26.5 q/ha, which was a good yield in the locality under unirrigated conditions. Grain yields of triticale, sunflower, and safflower were 9.4, 9.7 and 13.3 q/ha, respectively. Triticale and sunflower were newly introduced crops in the area. The results suggest that safflower could grow well under this condition due to its deep rooting pattern which helps to extract moisture from a greater depth. Further, the left-over stored profile moisture after the harvest of soybeans and maize was enough to grow the following rabi crops like wheat, triticale, sunflower, and safflower. The yields of these crops were greatly enhanced by the application of a 5 cm deep come-up irrigation from the harvested stored water.

PLANTING METHODS EXPERIMENT

During the 1971 monsoon season at the Wheat Research Station, Powarkheda, an experiment was conducted to determine whether kharif crops could be successfully grown by providing surface drainage (2). Surface drainage was provided by different planting methods. Again the soil used was deep Vertisol containing about 60 percent clay and was extremely sticky when wet and hard when dry. The slope of the land ranged from 0.2 to 0.4 percent and the field had an adequate drainage outlet. Thus, the excess rain water was readily drained from the flat plots as well as from the ridged plots. Two crops, maize and soybeans, were planted using three methods of sowing--(a) flat sowing, (b) flat sowing followed by ridging, and (c) sowing on ridges.

The ridges for treatment (c) were formed using a bullock-drawn ridger about three weeks before planting. Several rains occurred after the ridges were formed which helped settle the soil and make a stable ridge. The ridge planting and fertilization was accomplished on the preformed ridges using a bullock-drawn ridge planter with a hand-seeder and fertilizer attachment (17). Flat planting in treatments (a) and (b) was accomplished by use of a bullock-drawn "desi" planter with fertilizer attachment. Adequate fertilization was provided for all treatments.

Results and Discussion

Rainfall data (2) by 5-day intervals are given in Table 6. These data indicate that there was a rainfall in every 5-day period from planting through mid-September. The total seasonal rainfall was 138.7 cm compared to an average annual rainfall of only 123.4 cm. In spite of the 12 percent above-normal rainfall and cloudy weather with minimum sunshine, it was encouraging to note that plant growth appeared to be good throughout the growing season, especially in the ridged plots. Grain yields for maize and soybeans are shown in Table 7. Grain yields in the ridged treatments were significantly higher than in either of the flat sown plots, in both maize and soybean. The average maize yield in the ridged plot was 42.6 q/ha which was 18 percent above that of the flat treatment. The average soybean yield in the ridged plots was 15 percent higher than that in the flat plots. Even though these percentage increases were not great, it should be noted that with a field slope of 0.2 to 0.4 percent, surface drainage was sufficient so that there was no standing water even in the flat plots. Thus, the growth and yield in flat treatments was far better than that observed in surrounding fields with micro depressions and/or fields surrounded by bunds.

The maize was harvested on October 13 and soybeans on October 21. In both cases, the whole plant was removed from the field, air dried, and threshed about two weeks later. Immediately after harvest, the land was ploughed in preparation for the rabi wheat crop. Since rain occurred in early October, the soil profile was well supplied with moisture and there was no problem in land preparation for the rabi wheat crop. The wheat crop was planted about November 1 and was given a light irrigation to ensure uniform plant stands.

Table 5. Water use, growth, and yields of crops grown during rabi season (post-monsoon) on the run-off plots by utilizing profile moisture storage and part of harvested water.

Profile use (cm)	CROP			
	Wheat	Triticale	Sunflower	Safflower
0 - 100 depth (cm)	13.2	13.4	12.4	14.7
100 - 200 depth (cm)	4.0	4.5	8.0	9.5
"Come up" irrigation (cm)	5.0	5.0	5.0	5.0
Rainfall (cm)	1.0	1.0	1.0	1.0
Total water use (cm)	23.2	24.0	26.4	30.2
Open pan evaporation (cm)	53.0	53.0	53.0	53.0
Total dry matter (q/ha)	75.0	38.0	35.0	45.0
Grain yield (q/ha)	26.5	9.4	9.7	13.3

Although water harvesting was not included as a part of this experiment, some run-off measurements were taken, late in the season. Water harvesting is an essential facet of a total program of improved water management on the black cotton soils. This involves proper surface drainage for growth of kharif crop plus harvest and storage of the excess monsoon water for use in the subsequent rabi crop.

GENERAL DISCUSSION

As mentioned earlier, in the central and eastern parts of Madhya Pradesh there are extensive areas of fine-textured black soils (Vertisols) that are not effectively used during the rainy season because of difficulties in land preparation, timely planting, and poor crop performance caused by imperfect surface drainage. The results of the four experiments conducted in two locations of the area suggest that improved water management practices such as surface water removal by land shaping and ridging or bedding of the soil surface can greatly increase the yields of kharif crops of soybeans and maize. Further, under these conditions soybeans give much higher yield compared to maize, probably due to their tolerance to excess moisture conditions whereas maize is very sensitive to water-logging. Not only is the higher yield of soybeans an advantage over maize, but also soybeans fetch more money per unit weight of produce (4).

The most significant finding of these experiments was that it is possible to capture and store run-off water and to utilize it for irrigation during kharif and for the following rabi crops. This is known as water harvesting. The results indicate that by providing surface drainage it is possible to grow soybeans and maize successfully and, in addition, run-off water can be captured and stored for supplemental irrigation purposes. It is frequently observed in the area that even during the rainy season, there is a need to provide supplemental irrigation at the critical growth stages of the crop when rainfall is not evenly distributed. A single supplemental irrigation at a particular critical growth stage may even increase the yield by 100 percent. In the area wheat is the number-one crop grown in rabi season under unirrigated conditions. The greatest difficulty encountered is to have uniform stand establishment of wheat at the early stages of growth, i.e., during germination and emergence. Establishment of a uniform stand, it is observed, contributes greatly to higher yield of any crop. This can be achieved by providing one "come-up" irrigation just after planting. Once plants are established uniformly at the beginning, they can grow well by spreading roots horizontally and vertically in search of moisture and nutrients. The results indicate that moisture stored in the soil profile at harvest of soybeans and maize in the area is sufficient to grow rabi crops under unirrigated conditions.

Table 6. Rainfall by 5-day intervals at Wheat Research Station, Powarkheda, Madhya Pradesh, India, 1971.

Month	Five-day interval (dates)	Rainfall (cm)	Monthly total (cm)	Monthly normal (cm)
May	19 - 24	3.8		
	25 - 31	0.6	4.4	1.1
June	1 - 5	4.9		
	6 - 10	7.9		
	11 - 15	0.0		
	16 - 20	0.0		
	21 - 25	12.4		
	26 - 30	4.3	29.5	19.3
July	1 - 5	0.3		
	6 - 10	1.4		
	11 - 15	16.2		
	16 - 20	4.8		
	21 - 25	7.7		
	26 - 31	14.6	45.0	43.9
August	1 - 5	2.3		
	6 - 10	1.4		
	11 - 15	1.1		
	16 - 20	1.3		
	21 - 25	1.3		
	26 - 31	13.4	21.1	39.7
September	1 - 5	6.9		
	6 - 10	17.2		
	11 - 15	0.3		
	16 - 20	0.0		
	21 - 25	0.0		
	26 - 30	1.8	26.2	21.5
October	1 - 5	5.0		
	5 - 10	7.5		
	11 - 31	0.0	12.5	2.9
Monsoon season totals			138.7	123.4

Table 7. Comparison of ridge-planting versus flat-planting on grain yield of maize and soybeans during kharif (monsoon season) 1971 at Wheat Research Station, Powarkheda, Madhya Pradesh, India (average of 6 replications).

Method of planting	Maize (q/ha)	Soybeans (q/ha)
Flat sowing	37.1	21.3
Flat sowing (ridged at 5 wks)	36.0	21.0
Ridge sowing	42.6	24.2
C_D at 5%	2.9	2.6
CV %	5.8	8.9

Quick surface removal of excess water can be achieved by gentle land shaping and "ridged" methods of planting. Due to the fine texture of Vertisols the above system does not induce soil erosion to a great extent. When run-off water is passed through an almost flat surface of rice-growing area at the bottom of the slope, the eroded soil particles, if any, are likely to be captured at the flat surface and clean run-off water is collected in the storage tank. The real problem is how to keep stored water for some time to be used later as irrigation. Water is lost through evaporation and percolation. Percolation can be checked by sealing the boundaries of the tank. Evaporation can be reduced by reducing evaporating surface area of the tank, i.e., square surface, and providing greater depth of the tank without changing its total capacity. However, further investigations on these aspects are necessary.

In the area there seems to be a considerable potential for double cropping. This possibility depends not only upon the generation of short-season, high-yielding varieties but also on the development of appropriate cultural practices. The introduction of adequate surface drainage seems a prerequisite for monsoon cropping on these soils. Also, there appears to be scope for the collection of surplus monsoon rainfall for supplementing the soil moisture status during drought periods in the monsoon and during the early post-monsoon period. The quantitative interrelationships between levels of soil and water management and control, effective utilization of rainfall, drainage, run-off collection (water harvesting) and recycling for supplementing available soil moisture, soil conservation measures, and systems of cropping merit investigations.

REFERENCES

1. Bhargava, O.D. 1971. Water harvest from maize and soybean plots under Jabalpur (India) conditions. M.S. thesis. Jawaharlal Nehru Agricultural University, Jabalpur.

2. Gupta, K.P., and B.A. Krantz. 1972. Possibilities of growing kharif crops on black soils in central Madhya Pradesh. Water Technology Center Progress Rpt. Indian Agr. Research Institute, New Delhi.

3. International Crops Research Institute for the Semi-Arid Tropics. 1973. The farming systems program. Pages 22-24. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India.

4. Jana, R.K. 1973. Agricultural studies of the Angat and Magat rivers irrigation systems. Feasibility Rpts. Asian Development Bank, Philippines.

5. Jana, R.K., A.S. Tomar, and M.B. Russell. 1971. Field methods for estimating soil moisture behavior. Proc., symposium on interaction of water and porous materials. India National Science Academy, New Delhi.

6. Jana, R.K., A.S. Tomar, and M.B. Russell. 1972. Power core sampler--a reliable tool for soil moisture behavior studies. Proc., annual convention. India Society of Agricultural Engineers, Jabalpur.

7. Krantz, B.A. 1972. Water as a manageable input in agriculture. Ind. Farming 22(2): 25-27.

8. Mitchell, R.L., and W.J. Russell. 1971. Root development and rooting patterns, *Glycine max* L. Merr., evaluated under field conditions. Agron. J. 63:313-316.

9. Pendleton, J.S., and E.E. Hartwig. 1973. Management. Pages 223-224 in Soybeans: improvement, production and uses. B.E. Caldwell, ed. Agronomy Series No. 16. American Society of Agronomy, Madison, Wis.

10. Peters, D.B., and L.C. Johnson. 1960. Soil moisture use by soybeans. Agron. J. 52:687-689.

11. Raper, D.C., and S.A. Barber. 1970. Rooting systems of soyabeans. I. Difference in root morphology among varieties. Agron. J. 62:581-584.

12. Rogers, H.T., and D.L. Thurlow. 1970. Water, key to high soybean yields. Alabama Agr. Exp. Sta. Highlights Agr. Res. 17(2):4.

13. Runge, E.C.A., and R.T. Odell. 1960. The relationships between precipitation, temperature and the yield of soybeans on the Agronomy South Farm, Urbana, Illinois. Agron. J. 52:245-247.

14. Shaw, R.H., and D.R. Laing. 1965. Moisture stress and plant response. Pages 73-94 in Amer. Soc. Agronomy, Plant environment and efficient water use. American Society of Agronomy, Madison, Wis.

15. Singh, J.N., and M.C. Saxena. 1969. Soybean at Pantnagar, India. Uttar Pradesh Agr. Exp. Sta. Tech. Bull. 6.

16. Somerhalder, B.R., and P.E. Schleusener. 1960. Irrigation can increase soybean production. Nebraska Agr. Exp. Sta. Quart. 7(1):16-17.

17. Swaminathan, K.R., and B.A. Krantz. 1972. Bullockdrawn ridge planter. Water Technology Center Progress Rpt. Indian Agr. Research Institute, New Delhi.

18. Thompson, L.M. 1970. Weather and technology in the production of soybeans in the central United States. Agron. J. 62:232-236.

19. Whitt, D.C., and C.H.M. van Bavel. 1955. Irrigation of tobacco, peanuts, and soybeans. Pages 376-381 in U.S. Department of Agriculture, Water: 1955 yearbook of agriculture. U. S. Government Printing Office, Washington, D.C.

20. Winter, S.R., and J.W. Pendleton. 1968. Soybean roots: how deep do they go? Soybean Dig. 28(7):14.

The Influence of Grass Mulch on Emergence, Growth, and Yield of Soybeans, *Glycine max* L. Merrill

R.B. Dadson and
K.B. Boakye-Boateng

One of the major problems in growing soybeans in the humid tropics is seedling emergence. Poor seedling emergence may be due to the fact that soybean seeds quickly lose their viability in storage, the soil surface crusts up easily and it is difficult for the cotyledons to penetrate the surface, and soil temperatures are so high that they inhibit hypocotyl elongation. By using a grass mulch, soil temperature, surface crusting, and erosion can be reduced and soil moisture conserved [Verma and Kohnke (8), Adams (1), Grebb (5)]. These changes are most likely to improve soybean stands. Verma and Kohnke (8), early U.S. workers on the effect of mulching on soybean, reported seed yield responses ranging from an increase of 390 kg/ha to a decrease of 81 kg/ha following mulching. When plant residue and glass wool were tested, yield increases were obtained. Fairbourn (4) reported over 300 kg/ha increase in soybean seed yields when gravel and maize stalk mulches were used on soybean and other crops. In Nigeria a trial with rice straw mulch caused a reduction in soil temperature and improved the establishment by about 66 percent (6).

Groundnuts and cowpeas grown in the tropics have also shown yield increases after mulching with plant material.

The use of mulch may therefore assist in obtaining a higher percentage of seedling emergence. Two field trials and one pot experiment were thus conducted to study the effects of grass mulch on emergence, growth, and yield of soybeans.

MATERIALS AND METHODS

Three varieties of soybean were used in the field trial and pot experiment. These were Hill (short, early maturing, determinate) and Kent (medium height and maturity, indeterminate) from the United States and CES 486 (tall, late maturing, indeterminate) from the Philippines. The field trials were conducted at the University of Ghana farm at Legon, lat. 5°N, in the major and minor rainy seasons of 1973, and were located on slightly acid, free-draining, silty loams which tended to crust badly after rains. There were six treatments arranged in a randomized complete block design with four replications in each trial. The six treatments were made up of the three varieties planted with and without grass mulch. *Panicum maximum* and *Sporobolus pyramidalis* at 5,400 kg/ha were used as surface mulch immediately after planting in the major and minor rainy seasons, respectively. Plot sizes were 4.5 m X 2.0 m with 50 cm between rows. Seeds obtained from the preceding season's planting were used in the following season's trial. Seeds were treated with the commercial inoculant Nitragin before being sown at a depth of 3 cm with spaces between seeds approximately 5 cm. No fertilizer was added to either field trial, and no precautions were taken against pests and diseases. The trials were sprinkler irrigated as necessary.

Records were taken on initial plant stand, days to first flowering and maturity, plant apex height at first flowering and maturity, 100-seed weight and yield. Plants from 8 m of the center two rows in each plot were pulled by hand after maturity dates (95 percent pods browned) were recorded. The crop was shelled by hand. Seed moisture content was determined with a grain moisture tester (Dickey John Corp., Auburn, Ill., U.S.A.) and yields were converted to 13 percent moisture. Nodules were counted on 10 plants selected at random from each plot at the pod filling stage. Total dry weight of 10 plants was determined from each plot when bottom leaves were beginning to senesce. Pods per plant and main stem nodes were determined at harvest. Soil temperatures at 2.5 cm depth were recorded in all plots within 1 hour of application of mulch using soil thermometers. Daily soil temperatures were subsequently taken at 1500 hr. On the eighth day after planting, soil temperatures were taken at 1 or 2 hr intervals for 24 hr. In the minor rainy season planting, soil temperatures were determined on three different days between 0600 and 1200 hr (Fig.1).

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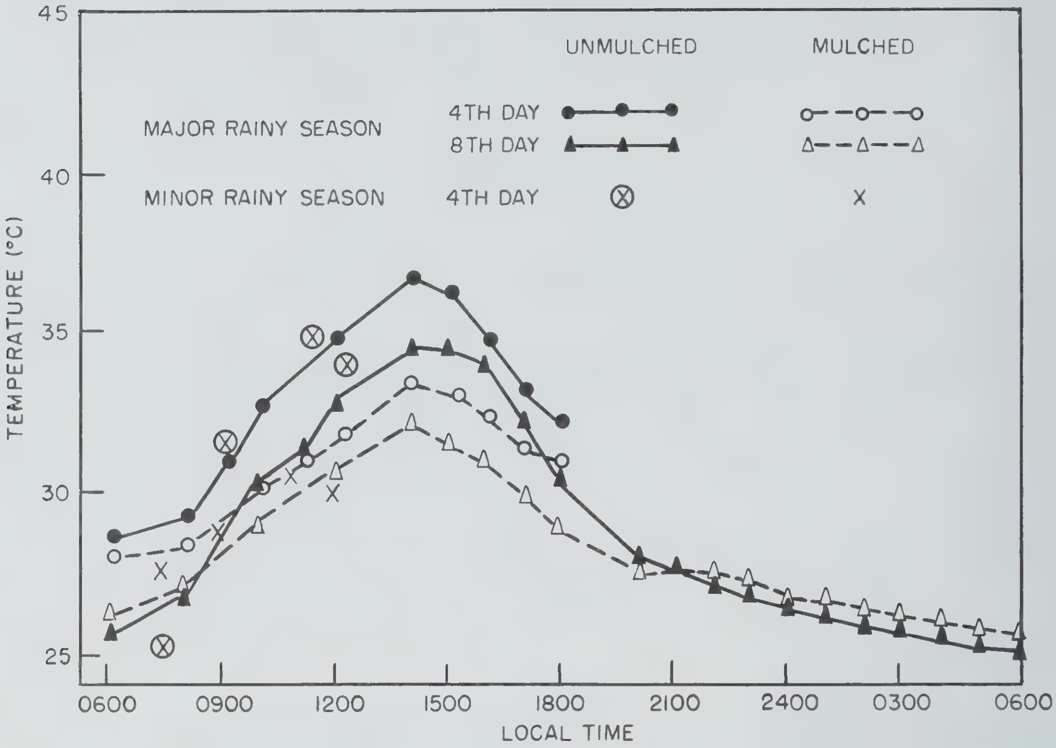

Fig. 1. Effect of grass mulch on soil temperature in soybean plots, Legon, Ghana.

Soil moisture contents were determined from soil taken from 2.5 cm deep in each plot after mulching and 10 days later during the minor season. (As there were frequent precipitations in the major season planting, no soil moisture records were taken during that season.)

In the pot experiments, seeds were planted in 15 cm diameter X 15 cm deep black paper-pulp pots filled with 1:2:1 mixture of sand : loam : humus. A randomized block design was used with four replications. Five seeds were planted in each pot and a mulch of dry grass of *S. pyramidalis* was applied at 11 gm per pot (about 5,500 kg/ha). Seedlings were thinned to one plant per pot 10 days after emergence. The plants were grown in the open and watered daily. Data collected included plant height; stem diameter; days to first flowering and maturity; number of flowers and pods set; number of mature pods, nodes, and branches on main stems; and seed yield.

RESULTS AND DISCUSSION

Effect of Mulching on Soil Temperature and Moisture

In both the major and minor rainy season trials, soil temperatures were similar in all plots irrespective of variety. Mulched plots were consistently 3.5^{o}C cooler than unmulched plots during the warmest daily periods (Fig. 1). However, in the early morning and night recordings, mulched plots had slightly higher minimum temperatures.

Soil moisture content in all mulched plots in the minor season averaged 14.9 and 13.9 percent immediately after mulching, in the mulched and unmulched plots, respectively. Ten days after planting and no rain, moisture content fell to 10.5 and 8.7 percent for mulched and unmulched plots, respectively. Thus more water was conserved as a result of mulching.

Effect of Mulching on Emergence and Other Characters

In the major season planting, although emergence was poor in all treatments, mulching consistently increased the number of plants that emerged (Table 1). The seed quality was poor since it had been stored at ambient temperatures for over 5 months. Mulching therefore seemed to improve emergence where the seed viability was low.

Flowering dates were not affected by mulching. Plant height at flowering, however, showed increases in the mulched plots. Since the stand was generally poor it is unlikely that interplant competition for light could cause etiolation. Although the stand at maturity had decreased in all plots, there were more and taller plants in the mulched than unmulched plots. Hill, a short, determinate variety, responded less than the taller, indeterminate CES 486. Mulching did not affect the time of maturity.

The yields of seeds of all varieties were increased by mulching. The moisture content of seed at shelling was higher in the mulched than unmulched plots, probably because of a slower drying rate in the mulched plots.

In the major season trial the incidence of *Sclerotium rolfsii* was higher in mulched than unmulched plots. This disease, however, did not seem to affect the yields.

Effect of Mulching on Emergence and Other Characters

The stand during the minor rainy season was not affected by mulching (Table 2). The seed used for planting this trial was only 3 months old and had been stored in polythene bags and was of high viability. A lack of precipitation within 10 days of planting reduced the risk from surface crusting, which would hamper emergence. The effects of mulching on plant development in the minor season were similar to those in the major season. Plant height at first flower and maturity, nodes on main stem, and pods per plant were all increased by mulching. Grain yields, however, were not increased by mulching. The total plant dry weight was only slightly increased by mulching. The lack of yield response to mulching could be due to the higher incidence of lodging and mouse damage of immature pods of CES 486 and Hill, respectively, on mulched plots.

Effect of Mulching on Plants Grown in Pots

There were greater responses to mulching of plants in pots than in the field (Table 3). Flowering was consistently earlier in the plants in the mulched pots. This was not always the case in the field. Mulching also increased plant height at first flowering and maturity, total number of flowers per plant in all varieties, the percentage of flowers which formed pods in Hill and Kent, stem diameter, main stem nodes, pods per plant, and seed yield.

It appears that soybean stands are generally improved by applying grass mulch when the seed viability is low. This occurred because of less crusting of the mulched soil. It is unlikely that the soil temperatures observed in the field were high enough to inhibit emergence of seedlings. For example, when Hill and CES 486 with 19 other varieties were allowed to germinate in soil in an incubator at 30^{o}C and 40^{o}C emergence was not much lower at 40^{o}C. Wein (9), however, reported that at 42^{o}C hypocotyls of Kent elongated very little. An attempt was made to separate temperature and moisture effects on emergence by growing the three varieties on plots covered with white wheat flour, black charcoal, and on bare soil. Although similar differences in soil temperature as great as those between mulched and unmulched plots were measured, emergence was not significantly different for the treatments. Thus, soil moisture conservation and reduced crusting under mulch are more crucial to emergence of soybeans than decreased soil temperatures.

The trials indicated that mulched soybeans grew taller and larger and often produced more pods than did unmulched plants. There was no attempt to determine the effect of higher moisture content and lower maximum temperatures separately. Although mulching reduced soil temperatures initially it is unlikely that mulching would be an important factor in temperature control once the soybean crop has developed a complete leaf canopy. It may therefore be concluded that if lower soil temperature aids in soybean development then the effect is critical only during the early growth of the crop.

The possibility that mulching may introduce diseases to the soybean crop, particularly in the major rainy season, should not be overlooked.

Table 1. Effect of mulching on emergence, growth, and yield of three soybean varieties grown during the major rainy season, Legon, Ghana, 1973.

Variety	Treatment	Initial stand (plants/m^2)	Days to flower	Plant height at first flower (cm)	Stand at maturity (plants/m^2)	Plant height at maturity (cm)	Days to maturity	Grain yield (kg/ha) (13% moisture)	Moisture content at shelling (%)	100-seed wt (g)
Hill	Control	12.9	27.0	23.1	10.0	25.2	90	1,026	11.9	17.4
	Mulched	19.4	27.0	25.2	15.8	26.6	91	1,914	12.2	17.4
Kent	Control	3.7	23.8	21.1	2.3	38.6	103	641	11.5	20.9
	Mulched	8.0	23.3	23.6	5.7	44.6	100	1,334	11.7	22.1
CES 486	Control	5.8	41.0	36.8	3.9	82.4	120	1,840	8.6	18.5
	Mulched	11.9	40.8	41.8	7.7	90.3	120	2,551	9.2	19.8
Source of variation										
Varieties (V)		**[b]	**[b]	**[b]	**[b]	**[b]	**[b]	**[b]	**[b]	**[b]
Mulching (M)		**[b]		**[b]	**[b]	**[b]		**[b]	**[b]	**[b]
V x M						*[a]				
CV (%)		31.2	1.8	5.4	34.3	4.0	2.4	27.9	3.1	4.5

a/ Significant at $P = 0.05$.

b/ Significant at $P = 0.01$.

Table 2. Effect of mulching on emergence, growth, and yield of three soybean varieties grown during the minor rainy season, Legon, Ghana, 1973.

Variety	Treatment	Initial stand (plants/m^2)	Stand after thinning (plants/m^2)	Days to flower	Plant height at first flower (cm)	Total plant dry wt at late podfilling (g)	Stand at maturity (plants/m^2)	Height at maturity (cm)	Days to maturity	Nodes per plant	Pods per plant	Lodging score 1 (erect) to 5 (flat)	Grain yield kg/ha 13%	Moisture at shelling (%)	100-seed wt (g)
Hill	Control	126	91	27.0	21.8	2.96	77	36.3	78	8.2	11.0	2.5	1,264	8.9	13.6
	Mulched	110	87	26.0	25.4	4.86	79	39.3	84	8.6	12.4	2.9	1,168	9.0	15.2
Kent	Control	75	66	23.3	17.8	5.26	59	46.2	85	11.0	15.9	1.3	1,678	9.0	17.0
	Mulched	67	65	23.0	22.3	5.80	66	55.8	85	12.0	17.9	2.5	1,859	9.1	17.7
CES 486	Control	124	90	32.3	29.8	3.83	79	64.5	94	10.7	12.9	3.4	1,076	8.4	15.4
	Mulched	141	92	33.0	35.3	4.34	83	80.8	95	12.6	18.4	4.6	1,328	8.6	16.9
Source of variation															
Varieties (V)		**b/	**b/	**b/	**b/	*a/	**b/	**b/	**b/	**b/	*a/	**b/	**b/		**b/
Mulching (M)					**b/			**b/		**b/	*a/	**b/			**b/
V x M				**b/											
CV (%)		18.0	11.8	1.7	7.3	26.0	11.5	9.8	2.6	7.3	23.1	16.9	21.8	6.6	5.2

a/ Significant at $P = 0.05$.

b/ Significant at $P = 0.01$.

Table 3. Effect of mulching on growth, flowering, and yield of three varieties of soybeans grown in pots, Legon, Ghana.

Variety	Treatment	Days to flower	Plant height at first flower (cm)	Flowers per plant	Stem diameter at first trifoliate node (mm)	Total number main stem nodes	Plant height at maturity (cm)	Number branches per plant	Total pods per plant	Pods per plant at maturity	Nature pods per flower (%)	Seed yield (g/plant)
Hill	Control	30.3	20.6	44.8	5.6	8.8	27.5	4.8	22.8	14.3	30.3	4.6
	Mulched	29.0	24.7	56.5	6.6	9.1	29.6	5.8	34.1	28.0	47.3	7.7
Kent	Control	26.5	13.2	25.9	5.0	8.5	24.3	5.0	11.3	8.4	33.0	2.3
	Mulched	26.0	17.3	44.9	6.7	10.1	31.9	6.8	22.5	17.4	38.5	5.5
CES 486	Control	40.0	24.0	51.9	6.4	10.9	31.4	5.5	19.0	17.4	30.2	3.1
	Mulched	38.3	30.2	90.4	8.3	14.1	40.8	6.8	34.8	28.4	30.2	6.7
Source of variation												
Varieties (V)		**b/	**b/	**b/	**b/	**b/	**b/		*a/			
Mulching (M)		**b/	**b/	**b/	**b/	**b/	**b/		**b/	**b/	*a/	**b/
V x M						*a/						
CV (%)		2.3	8.0	28.0	13.4	8.6	11.9	38.3	35.9	43.7	22.2	36.6

a/ Significant at $P = 0.05$.

b/ Significant at $P = 0.01$.

Ghana may in the near future introduce soybeans into the farming system. The small-scale farmer may improve the stand of his crop through the use of grass mulch. On a large commercial scale, however, the application of grass mulch is limited. In this case the incorporation of plant residues, such as chopped maize, sorghum, or rice straw--when these precede soybeans in the rotation--would reduce crusting and improve the water-holding capacity of the soil to the benefit of the soybean seedling.

REFERENCES

1. Adams, J.E. 1965. Effect of mulches on soil temperature and grain sorghum development. Agron. J. 57:471-474.
2. Ashrif, M.I., and I. Thornton. 1965. Effects of grass mulch on groundnuts in the Gambia. Expl. Agric. 1:145-152.
3. Cooper, R.L. 1971. Influence of early lodging on yield of soybean (*Glycine max* L. Merr). Agron. J. 63:449-450.
4. Fairbourn, M.O. 1973. Effect of gravel mulch on crop yields. Agron. J. 65:925-928.
5. Grebb, B.W. 1966. Effect of surface-applied wheat straw on soil water losses by solar distillation. Soil Sci. Soc. Amer. Proc. 41:593-598.
6. International Institute of Tropical Agriculture. 1973. Grain legume improvement program 1973 report. Pages 58-59. International Institute of Tropical Agriculture, Ibadan, Nigeria.
7. Nye, P.H. 1952. Studies on the fertility of Gold Coast soils, IV. The potassium and calcium status of the soils and the effects of mulch and kraal manure. Emp. J. Exp. Agr. 20:227-233.
8. Verma, A.B.S., and H. Kohnke. 1951. Effect of organic mulches on soil condition and soybean yields. Soil Sci. 72:149-156.
9. Wien, H.C. 1973. Grain legume physiology at IITA. In Proc. first IITA grain legume improvement workshop. Pages 105-114. International Institute of Tropical Agriculture, Ibadan.

DISCUSSION

Z. OUMER: How could mulching be used in peasant agriculture, in view of the broadcast sowing? Even in peasant agriculture soybeans must be planted in rows.

R.B. DADSON: Soybean seeds have to be put in the soil at about 5 cm deep to get the seed in good contact with the soil for it to be able to imbibe moisture to start the germination process.

H.A. VAN RHEENEN: In the early planted mulch trial, how were the yields per ha calculated? (Yields per ha up to 2,000 kg showed only about 20 percent.)

DADSON: The yields were based on a total of 8 m rows taken from the center two rows.

E.T. MMBAGA: How do you eliminate fire and termite hazards?

DADSON: Fire hazards could be reduced by plowing an area of about 5 yards around the field. Termites can be controlled with any pesticide or Arkoline.

T.I. ASHAYE: If these experiments finally prove that mulching is the answer to economic yields of soybean, how do you intend to incorporate the findings into the farming system in your country?

DADSON: Soybeans will be grown in rotation with corn, sorghum, or rice. Hence, there will be mulch material in the next season left on the field for the soybean when it follows these cereal grains.

W. PLARRE: Did you observe any differences in the attacks by diseases?

DADSON: The attack of *Sclerotium rolfsii* was uniform in all plots.

S. MOUTIA: In other crops, when raw or fresh organic matter is applied as mulch we find we should increase our application of N. What is the position in soybeans?

DADSON: The question has not been investigated, but it is certainly of importance, or the C/N value is upset, especially in the early stages of the crop.

G.F. NSOWAH: Did you observe any damage from crows' eating the emerging cotyledons? If so, did you establish any differences between the mulched and the unmulched plots on the varieties?

DADSON: Crows have not been a problem in our plots. There is no doubt that mulching would offer shelter protection to the emerging seedlings.

E. HERATH: Was the incidence of lodging and the higher yield data due to unutilization of organic matter from mulching as compared to data from unmulched plots?

DADSON: Also mulching would rather have caused an imbalance of the C:N ratio in the soil, which would mean the available N under these field conditions.

Intercropping Soybeans with Cereals

R.C. Finlay

The soybean (*Glycine max* L. Merrill) has an ancient history, as does the subsistence farmer's cropping system.

Soybean has become the most important legume in the Western Hemisphere (3). Probably the most important food legume in Africa is cowpea. Ninety-eight percent of cowpeas grown in Africa are intercropped (5).

Mixed cropping or intercropping is a husbandry system in which different crop mixtures are grown at the same time on the same area of land. There are other forms of this system such as relay cropping, which has a marked time of planting component, and multiple cropping, in which more than one crop harvest per season is obtained.

In 1936, Wilson and Burton (34) at the University of Wisconsin, wrote, "Although mixed cropping has long been used in agriculture, little progress has been made toward an understanding of the origin of the benefits arising from the practice." Forty years later this statement is still valid. There is little quantitative information available on the comparative merits of intercropping and monoculture.

A study (25) conducted in northern Nigeria showed that, in general, the profitability of crop mixtures over sole crops was about 60 percent. This particular study was conducted on locally grown annual crops under indigenous technological conditions. Under improved technological conditions, the superiority of intercropping as a farming system has also been demonstrated (4, 6, 11, 12, 14, 29) and in some cases recommendations have been made (6, 11-13, 19, 24, 27, 32).

With the serious research effort being placed today on crop production within the framework of a farming system, renewed interest has been generated in mixed cropping. Fisher (17) has reviewed mixed cropping from a plant physiologist's viewpoint and Norman's study (25) covers the economic considerations. African scientists at the University of Dar es Salaam have initiated a program (16) to study and improve intercropping systems through plant breeding, agronomy, and crop protection.

As a cultural practice, the reasons for the popularity of intercropping among small farmers in tropical environments are:

a) Flexibility. Sowing and planting dates can be arranged so as to optimize labor requirements during cultivation and harvesting (25, 30).

b) Profit maximization. Higher output with higher yields per unit area of land (6, 11, 12, 14, 25, 30).

c) Resources maximization. On a given area of land, mixed cropping maximizes the returns from the most limiting factors (shortages). Resources and their use in a mixed cropping system can be considered in terms of a dimension of space and time: Space--a vertical and horizontal arrangement of stems, leaves, and roots and land area, light, and so on. Time--water, nutrients, temperature, labor, crop cover and duration, and so on.

In considering that the chief constraint for a small farmer who uses hand tools is his own labor, and, in some cases, land area (30), the importance of receiving maximum return from these two inputs adds merit to a mixed cropping system. Baldy (7) has reviewed water utilization in mixed cultures. Few conclusions can be drawn until more information on mixed cropping under different fertility levels and rainfall regimes becomes available.

A mulch or shading effect on the soil and roots to alter the temperature and microclimate in a canopy is practiced by subsistence farmers through manipulating tall and low-growing crops.

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d) Risk minimization. Insurance against insects, diseases, weather, price fluctuations, and so on--a cropping system that utilizes an ecological balance between a farmer and his environment.

Data on cowpeas in an intercropping system at Morogoro (16) indicated that the cereal may impede the movement of legume insects, causing them to be more aggregated than in a monoculture system. Any system that offers a dependable return on a subsistence farmer's input of scarce resources will become popular, as have different farming systems in different parts of the world.

e) Soil conservation. Utilizes the benefits of a long period of ground cover to protect the soil from water and wind erosion.

Yields of soybeans increased 20 to 25 percent using maize as a temporary windbreak in a mixed cropping system tested near Dumont, Minnesota (29). The conservation of water was believed to be more efficient since the amount of water used was unchanged. However, other factors, such as air-flow in relation to canopy structure may also be important.

f) Soil fertility maintenance. Higher retention of soil fertility (a type of crop rotation practiced each season on the same land); nitrogen fixation by legumes; root excretions; mycrorrhiza; root feeding at different levels and over different periods of time; adaptation of planting to changing soil conditions--all are factors in an intercropping soil management system.

A true sorghum monoculture system in northern Nigeria resulted in a dramatic yield depression from the first to the second crop, after which yields declined gradually. This drop could be avoided by mixed cropping (19). Where mixed cropping was practiced, the adverse effects were avoided. Sorghum can be grown intercropped in the same field for several years.

Nitrogen fixation and excretion by soybeans and other legumes in an intercropping system require urgent attention because of the increased price and nonavailability of nitrogen fertilizers to large numbers of small farmers in the tropics.

Early work at Wisconsin (34, 35) indicated possible benefits in the form of excretions. Greengram may improve the yield of a companion crop such as maize; whereas cowpeas may do better in a rotation system (1). However, there is the other possibility that cereal excretions could also benefit the legume (22). The importance of the shading effect on legume nodules will have to be examined in an intercropping system.

Different types of rooting systems (tap or fibrous or both) and feeding at different depths and over different periods of time are important areas for future study. Soybean, for example, takes up about 30 percent of its potassium needs and 40 percent of its phosphorus and nitrogen requirements from the soil after the seed filling stage begins. However, maize accumulates all of its K requirements and 70 percent of its total P and N by this same stage.

g) Weed control. Soybeans, where well grown with early weeding because of their relatively slow early development, can, after 6 to 8 weeks, act as smother crop with a closed canopy (6). Crop competition is the cheapest and most useful method the small farmer has to control weeds.

h) Nutritional reasons. A continuous supply of varied foods over several months, with balanced nutrition, can be partly achieved through a mixed cropping system. Frequency of consumption depends partly on storage, which is generally a problem. In Tanzania, soybean stores better than any of our other legumes (30).

i) Sustenance income. From companion crops which may require little or no additional input (13).

j) Traditional popularity. The system has proven its worth to the small farmer throughout the tropics over a long period of time.

The chief disadvantage of an intercropping system is the need for mechanical harvesting. Evans, working in Tanzania, wrote, "Unless sound evidence is obtained that production from pure stands is appreciably higher than that from mixed cropping and that there are advantages such as reduced labor input, pest and disease control, and convenience, it will not be possible to introduce rotational systems of agriculture based on pure stands as long as the hoe remains the most important agricultural implement" (11).

Our failure to adequately understand traditional agriculture systems, in attempting to increase crop production, has no doubt strongly contributed to our past failures, with the subsequent waste of development capital and loss of production (16).

Mixed cropping is practiced in Europe for silage production. Good yields of dry matter and feed value have been obtained (22) with a cereal-soybean mixture. The few studies (2, 4, 28, 29, 35) that have been conducted in the United States have produced positive results. Soybeans intercropped with sugar cane (27), castor (12), cotton (4), and wheat (26) emphasize the flexibility and potential of soybeans in a mixed cropping system.

Improvements through the use of modern technology and innovations applied to this traditional crop husbandry system could prove difficult because of the infinite number of possible combinations and the other complexities involved.

However, with the development of genetic male sterility (8) and its application in a recurrent selection program using broad-based genetic populations, soybeans can be bred directly in and for crop mixtures. At Morogoro, we are presently using recurrent selection schemes for maize (16) and sorghum (15). Our experience in the use of Coes male sterility in sorghum (15) should also assist us in using male sterility in soybeans efficiently. Pollen transmission in any recurrent soybean selection scheme is essential, and with our high populations of insects and bees, natural crossing may have to be controlled and directed for random mating purposes. Gordienko (20, 21) produced an average of 35 percent hybrid seed by caging two varieties of soybean with honey bees. Other soybean workers (3), however, have not obtained such promising results.

Varietal soybean mixtures have not, to date, proved successful in the United States (3, 9), although mixtures have demonstrated a possible benefit under Tanzanian conditions (6). Therefore, varieties selected and tested in normal monoculture breeding programs may not perform well as mixtures.

An attempt to screen our best Tanzanian germ plasm at Morogoro under three different cereals is presented in Table 1. The diversity of germ plasm now available (3) and the future prospect of producing broad-based genetic populations with shade tolerant (10), improved nitrogen fixation and root excretion systems (1, 34, 35), as well as the possibility of producing higher protein values from soybean (31), make the intercrop-recurrent selection scheme with sorghum or maize an attractive and challenging undertaking. Yield is the objective and plant type will probably be branched (26), determinate (3), a large bush type (weed suppressing), small seeded (6) and a full-season variety with an ability to fully utilize local soil *Rhizobium*. Any practical germ plasm collection should contain resistance to lodging, shattering, nematodes, insects, and diseases. Usually an intercropping system has a balanced nutritional supply of emergy and protein built into it (30).

Only a portion of the system involves a legume; the cereal should be handled with equal importance. If the Nebraska success (18) in selecting for high grain yield in maize by mass selection is any indication, then selection in an intercropping system for two-eared plants at wide spacings should also prove productive. The harvest index, in terms of economic yield and water and light use, might also be improved by reducing height in our present tropical cereals.

Before embarking on a testing, crossing, or agronomy intercropping program, spacings as well as plant populations should be carefully examined. The difference between planting in the same row and in alternate rows is clearly indicated in Table 2. The flexibility of the system makes management decisions necessary in order to maximize yield and returns in the form of food value and income. An experiment at Ilonga, Tanzania, in 1972 showed that 31 percent more land area was required to produce the same amount of maize and soybeans under monoculture conditions as compared to the intercropping system (Table 2).

Yields under different fertility conditions for both systems are presented in Fig. 1. The positive association of intercrop grown under fertilized and nonfertilized conditions in terms of total yield is clearly demonstrated.

Competition factors as well as beneficial effects can be misleading in an intercrop. Table 1 clearly shows the harmful effect (yield depression) that millet has on soybean yields when compared to maize or sorghum. However, millet yields are higher in the intercrop than in the monoculture check. The situation is further complicated as Fig. 2 shows a positive response in terms of increased maize yield to *Rhizobium* inoculated soybeans. Choudhury, a soil microbiologist at Morogoro, developed this particular inoculum, which consists of a combination of local isolated strains and was initially tested in 1973. The residual effect of this experiment will be field tested in 1975.

Table 1. Intercropping of three different cereals and twelve soybean cultivars showing mean grain yield in quintals/hectare.

Cultivar	Monoculture	With maize	With sorghum	With millet
1H/192	15.5	7.2 (1)[a/]	8.7 (1)	3.1 (4)
HLS 223	15.7	4.9	6.4	2.2
7H/101	16.2	5.4	4.3	2.3
H237	12.3	4.9	5.0	2.2
Light speckled	16.3 (4)	6.4 (3)	7.5 (4)	2.6
Un.	12.4	5.5	5.5	2.6
3H/149/1	16.5 (3)	5.1	7.8 (2)	3.2 (3)
3H/1	18.8 (1)	6.9 (2)	7.3	3.4 (1)
9H/100/5	12.9	4.7	5.5	2.9
10H/348	13.0	5.5	6.3	2.7
CHF	18.2 (2)	5.7 (4)	5.8	2.8
3H/9/1	15.1	5.3	7.6 (3)	3.3 (2)
Mean total	15.2	5.6	6.5	2.8
Percentage of monoculture (soybean)	100	37	43	18
Mean cereal only	--	29.4	13.3	34.7
Total cereal + soybean	--	35.0	19.8	37.5
Check--cereal monoculture	--	30.9	13.6	28.9

a/ Numbers in parentheses indicate ranking.

Table 2. Intercropping of cereals and legumes (14) showing mean grain yield in quintals per hectare.

Treatment	Cereal	Legume	Total	Intercrop as percentage of monoculture plots: Cereal	Legume	Cereal + legume
1) Maize (75 x 30 cm)	56.6	--	56.6	--	--	--
2) Sorghum (60 x 20 cm)	38.8	--	38.8	--	--	--
3) Soybean (75 x 10 cm)	--	17.7	17.7	--	--	--
4) Cowpea (75 x 30 cm)	--	10.0	10.0	--	--	--
5) Maize + soya (same row)	52.0	6.9	58.9	92	39	131
6) Maize + soya (alternate rows)	36.1	11.7	47.8	64	66	130
7) Maize + soya (alternate 2 rows)	31.3	8.8	40.1	55	50	105
8) Sorghum + soya (same row)	31.5	6.0	37.5	82	33	115
9) Sorghum + soya (alternate rows)	24.7	7.8	32.5	64	44	108
10) Sorghum + soya (alternate 2 rows)	24.5	7.9	32.4	63	45	108
11) Maize + cowpeas (same row)	40.0	3.0	43.0	70	30	100
12) Sorghum + cowpeas (same row)	27.8	1.8	29.6	71	18	89
13) Maize (same row) + sorghum	45.6 9.4	--	55.0	81 24	--	105
14) Maize (alternate rows) + sorghum	34.4 12.4	--	46.8	60 32	--	92

CV 12.9 %
SE ±2.54
LSD 7.24
P = 0.05

S_1 = 1 H/192 (10 cm APART IN THE ROW BETWEEN MAIZE PLANTS)
S_2 = 1 H/192+IC (75 cm BETWEEN ROWS x 40 cm IC)
S_3 = 1 H/192 MONOCULTURE (75 x 10 cm)
P_0 = 0 kg/ha OF P_2O_5
P_1 = 80 kg/ha OF P_2O_5

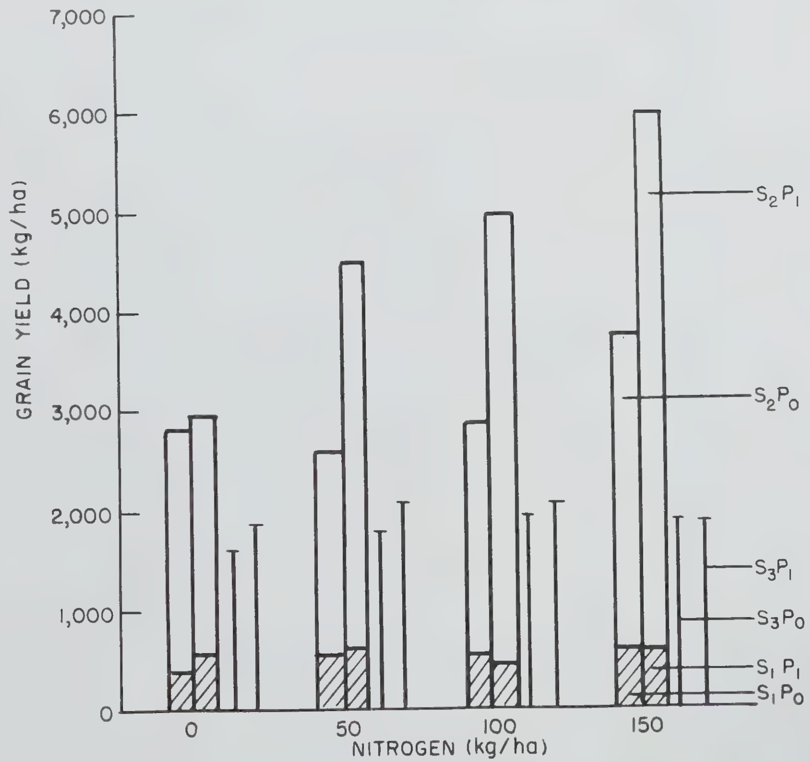

Fig. 1. Mean grain yield of soybean intercrop (S_1), soybean + maize intercrop (S_2), and soybean monoculture (S_3), without phosphate (P_0) and with phosphate added (P_1), at four levels of nitrogen.

S_1 = 1 H/192 (10 cm APART IN THE ROW BETWEEN MAIZE PLANTS)
S_2 = 1 H/192 + IC (75 cm BETWEEN ROWS x 40 cm IC)
I_0 = NO INOCULUM
I_1 = INOCULUM (COMBINATION OF LOCAL STRAINS)
P_0 = 0 kg/ha OF P_2O_5
P_1 = 80 kg/ha OF P_2O_5

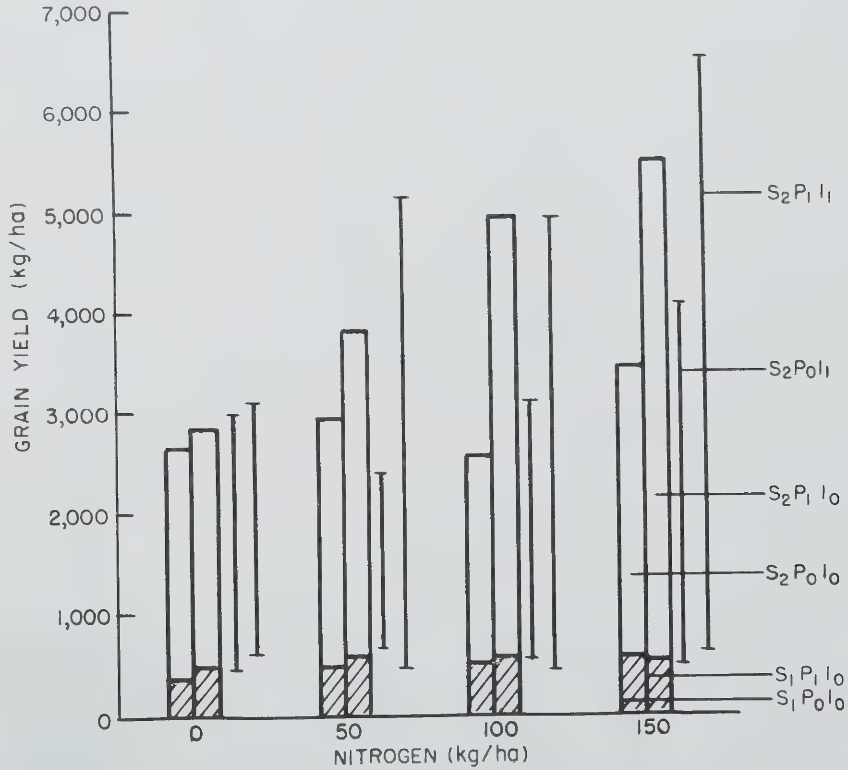

Fig. 2. Mean grain yield of soybean intercrop (S_1), and soybean + maize intercrop (S_2), under noninoculated (I_0) and inoculated (I_1) conditions, without phosphate (P_0) and with phosphate added (P_1), at four levels of nitrogen.

Studies for crop production recommendations, such as time of planting; plant population--seeding rates and row widths; planting depth; need for inoculation; fertilizer rates, placement, and time of application; disease, insect, and weed control; and harvesting procedures, must all be conducted for a soybean intercrop. Variety recommendations should begin by testing within a standard intercropping system. If soybean is ever to become accepted as a basic food commodity or cash crop or both on the African continent, in terms of nutritional or economic improvement among the majority of African farmers, then a place for it must be found within the diet of the people and within their own crop production system.

REFERENCES

1. Agboola, A.A., and A.A. Fayemi. 1972. Fixation and excretion of nitrogen by tropical legumes. Agron. J. 64:409-412.

2. Alexander, M.W., and C.F. Genter. 1962. Production of corn and soybeans in alternate pairs of rows. Agron. J. 54:233-234.

3. American Society of Agronomy. 1973. B.E. Caldwell, ed. Soybeans. Amer. Soc. Agron. Mono. 16.

4. Anonymous. 1963. Skip-row cotton. Soybean Dig. 23(9):14.

5. Arnon, I. 1972. Crop production in dry regions. Vol. 2. Leonard Hill, London.

6. Auckland, A.K. 1970. Soyabean improvement in East Africa. In C.L. Leakey, ed. Crop improvement in East Africa. Commonwealth Agr. Bur., Eng. Tech. Comm. 19 of Commonwealth Bur. of Plant Breeding & Genetics.

7. Baldy, C. 1963. Mixed cultures and water utilization. Ann. Agron. 14:489-534.

8. Brim, C.A. 1973. Quantitative genetics and breeding. Chapter 5 in B.E. Caldwell, ed. Soybeans. Am. Soc. Agron. Mono. 16.

9. Caviness, C.E. 1966. Performance of soybean varietal mixtures. Arkansas Farm Res. 15(4):2.

10. Chen, K. 1961. The theoretical basis of intercropping, mixed cropping, and undercropping and its practical significance. In Sci. Abstr. China Biol. Sci. 1963, No. 5, Abstr. 223.

11. Evans, A.C. 1960. Studies of intercropping I. Maize or sorghum with groundnuts. E. Afr. Agr. For. J. 26:1-10.

12. Evans, A.C., and A. Sreedharan. 1962. Studies of intercropping II. Castorbean with groundnuts or soybeans. E. Afr. Agr. For. J. 28:7-8.

13. Food and Agriculture Organization. 1972. Improvement and production of maize, sorghum and millet. TF-IND 92 (SWE).

15. Finlay, R.C. 1974. A new sorghum breeding approach at Morogoro. A comparison of methods used in population breeding. The Fifth Eastern African Cereals Research Conference, Malawi.

16. Finlay, R.C., H.Y. Kayumbo, J.H. Monyo, and A.N. Mphuru. 1974. The Morogoro intercropping research project. The Fifth Eastern African Cereals Research Conference, Malawi.

17. Fisher, N.M. 1972. The productivity of mixed cropping in the tropics: A review of theoretical considerations and experimental findings. Sci. Comm. No. 1, Dept. of Appl. Plant Sci., Univ. of Nairobi.

18. Gardner, C.O. 1971. Development of superior populations of sorghum and their role in breeding programs. Pages 180-196 in Rao and House, eds. Sorghum in seventies.

19. Goldsworthy, P.R., and K.A. Watson. 1960. Guineacorn followed by guineacorn--a practice which should be avoided. Ministry Agr. N. Nigeria Newsletter 23:13-17.

20. Gordienko, V.A. 1960. Production of fertile hybrids of soya with the help of bees. Trud. Mold. Akad. Nauk. 2:31-39.

21. Gordienko, V.V. 1960. Sexual hybrids of soyabeans obtained by hired bee pollination. In Pollination of agricultural plants by bees. Vol. 3. Moldavian Agri. Inst. Russia.

22. Kalaidzhieva, S. 1969. Results of intercropping maize and soyabean. Int. Z. Landw. No. 2, pp. 196-201.

23. Kremnina, A.N., and V.A. Pronin. 1965. Root excretions from maize and their effect on some of the vital functions of soyabean plants. Fiziologiya Rast. 12(5):847-852. Field Crop Abstr. 18:1451.

24. Narang, S.D., et al. 1969. Intercropping of maize with soybean. Indian Farming 19(6):21.

25. Norman, D.W. 1971. Intercropping of annual crops under indigenous conditions in the northern part of Nigeria. Rural Economy Research Unit. Ahmadu Bello University, Samaru, Zaria, Nigeria.

26. Oizumi, H. 1962. Studies on the mechanism of branching and its agronomic considerations in soybean plants. Tohoku Nat. Agr. Exp. Sta. Bull. 25, pp. 1-95.

27. Pan, Y.C., and K.M. Lee. 1963. A study on the interplanting of sugar cane with soybean. Taiwan Sugar Exp. Sta. Rpt. 32, pp. 1-40.

28. Pendleton, J.W., et al. 1963. Alternating strips of corn and soybeans as solid plantings. Agron. J. 55:293-295.

29. Radka, J.K. 1968. Corn a profitable windbreak for soybeans. Soybean Dig. 28(7):17.

30. Ruthenberg, H. 1971. Farming systems in the tropics. Oxford Univ. Press, London.

31. Son, S.H., and K.Y. Chung. 1969. Effects of intercropping of sorgo and soybean on growth, yields and qualities of the two crops. Res. Rep. Office Rur. Dev., Suwon, Korea 12(1):117-123. Field Crop Abstr. 23:389.

32. Sulyman, M., et al. 1967. Maize and soybean mixed cropping in Peshawar region. W. Pak. J. Agr. Res. 5(3):5-8. Field Crop Abstr. 22:113.

33. Vanichyangkool, S. 1967. A comparison of corn yield at different rates of planting interplanted with soybean in the dry season. Thesis. Kasetsat University, Thailand. 37 pp. Field Crop Abstr. Vol. 24 No. 1611.

34. Wilson, P.W., and J.C. Burton. 1938. Excretion of nitrogen by leguminous plants. J. Agr. Sci. 28:307-323.

35. Wilson, P.W., and O. Wyss. 1937. Mixed cropping and the excretion of nitrogen by leguminous plants. Soil Sci. Soc. of Amer. Proc., pp. 289-297.

DISCUSSION

W.J. KAISER: Have you noticed any differences in the incidence of diseases and pests in soybean or cowpeas grown in pure stands versus those intercropped with cereals?

R.C. FINLAY: Yes, our observations, as well as those of the workers, are that there are fewer disease and insect problems in an intercropping-type system.

M. VON OPPEN: In India intercropping of soybeans in cotton turned out to be a failure as planting was to be done before the rainfall and during the period after planting seeds are losing their viability. Do you have suggestions to slow the problem?

FINLAY: Capsuling of the seeds may be a solution, to maintain viability. Mulching could offer another, more practical, solution. Small seed-size could also be an answer to the problem and different cultivars should be tried. Placing in a capsule or coating the seed might be the solution, but only if it is done economically.

E. ASENIME: Have you considered spacing as an important factor in obtaining good results in intercropping systems?

FINLAY: Yes, plant spacings as to seeding rates and row widths in order to obtain a desirable plant population of a particular plant type will have to be investigated for an intercropping system in terms of breeding and crop production.

W. PLARRE: I would like to make a comment relative to intercropping soybeans from the breeder's point of view. At IITA our main program, farming systems, is dealing with all the questions of intercropping, and we are confronted very often with all the problems involved. There is a challenge by the small holders to all of us--how can we improve the mixed cropping system? It has so many advantages pointed out by Dr. Finlay.

If we will test all the released varieties and newly developed strains to find out the best adapted genotypes suitable for mixed cropping, this would be too expensive and time consuming. In the past, man used soybeans as a monoculture and they were not selected for intercropping. Therefore, from the breeder's point of view I would like to recommend we should look for suitable genotypes in the germ plasm of the primitive types. Such material should be included in a cross program and we should use populations for screening the best adapted genotypes. These populations have to be planted in mixed cropping systems so that natural selection can take place to facilitate the chance for our selection work.

In the population program, vining types should be included as we can find them in the primitive forms. In their conversion also the indeterminable types will become very interesting. We started at IITA with a cross program in this direction, and we found promising new vining genotypes with good seed quality and other valuable characters in the segregating F_2-generation. Such populations will be taken over by our agronomist to conduct intercropping trials.

Seed Quality and Storage of Soybeans

J.C. Delouche

The soybean became a crop of worldwide economic importance only in the last 20 to 25 years. In the United States, the biggest producer, the acreage devoted to soybean increased over 300 percent during the period 1952-1972. Brazil, the second largest producer, has enormously expanded its soybean acreage and production in just the last few years. The very rapid rise of the soybean to the forefront among world commercial crops is solidly based on continual improvement in cultivars and production technology, and is fully supported at every point by a parallel development of the infrastructure essential for commercialization of the soybean. An important element of this infrastructure--at least in the Western Hemisphere--is the soybean seed industry.

As an introduction to the subject of "seed quality and storage of soybeans," I believe it is informative to review briefly the development and present status of the soybean seed supply industry in the United States. It is recognized, of course, that the situation in the United States, where soybeans are produced on a vast acreage primarily for processing into animal feed, edible and industrial oils, other industrial products, or for export, is very different from that in most developing countries where soybeans are only now being introduced mainly as a high protein food crop for direct consumption. Nevertheless, the soybean is a seed-propagated crop regardless of how it is handled and ultimately used, and the developing countries beginning soybean production will be confronted with all the problems encountered in soybean seed production-supply in the United States. In the developing countries these problems generally will be much more serious and difficult to solve because of unfavorable climatic conditions.

Soybean farmers in the United States recognized early that soybean seed was somewhat different from the "seed" of most other crops with which they were familar, e.g., maize, wheat, cotton, sorghum. Very often soybean seed germinated poorly even just after harvest, and germination further decreased during storage to the extent that, by the next sowing season, the seed was worthless for planting. Ordinary "seed saving" practices used by farmers for self-pollinated crops with "replacement" of the seed only every 3 to 4 yrs did not (and does not) work well for soybeans. Some farmers did learn to produce and store soybean seed of satisfactory quality through experience and installation of basic facilties, and some do save their own seed over several cropping seasons, but always with the option of obtaining the necessary planting seed from commercial sources or a neighbor whenever their own seed production efforts fail, which is rather frequent. Other soybean farmers, perhaps a majority, have turned increasingly to the specialized, professional seed producers and companies--the seed industry--for their entire seed supply.

Production of quality soybean seed is not without problems and risks even for the specialists and professionals. Their experience, facilities, and other resources, however, and their concentration on the single task of producing quality seed, have permitted the development of a responsible soybean seed supply industry capable of delivering moderate to good quality seed in quantities ample to meet the needs of soybean farmers.

The soybean seed industry in the United States consists of many seed companies located in all soybean producing states. This is necessary because soybean cultivars are rather narrowly adapted along north-south zones on basis of photoperiod, and within zones on the basis of a variety of factors including soil types, prevalence of diseases, and so on. Thus, seeds of specific cultivars generally must be produced within their area of adaptability. The seed companies involved in soybean seed production range in size from those which handle 10,000 to 15,000 bu per year (270 to 410 mt), to a few that market more than 500,000 bu annually (13,600 mt). Some of the seed is produced on land owned or otherwise controlled by the seed companies, but the largest portion by far is produced by

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hundreds of private farmers under contractual agreements with the companies, or as independents with sales after harvest to the highest bidding company.

Compared to maize, rice, sorghum, millet, and some other important crops, the soybean has a low seed multiplication ratio. Seeding rate is rather high and yields are rather low, so that 3 to 5 percent or more of the total production must be saved for seed. The supply of seed needed for any sizeable acreage, therefore, is relatively large. In 1972 about 900,000 acres (360,000 ha) were used to produce "certified" soybean seed in the United States. The production from this acreage was sufficient to plant about one-third of the 1973 crop. The other two-thirds of the soybean crop were planted with noncertified seed (which is not necessarily inferior in quality to certified seed) obtained from seed companies, neighbors, or "saved" by the farmers from their own production. Although the purchase of certified or private "brand" soybean seed is increasing, it is estimated that currently about 40 to 50 percent of the United States soybean crop is planted with farm-saved seed or seed purchased from neighboring farmers.

An important characteristic of the soybean seed industry in the United States is its flexibility and responsiveness to seed crop failures and supply shortages. Almost every year, soybean seed production fails in some area within a state or region because of adverse climatic conditions during the growing, maturation, or harvest periods. In such instances soybean seed moves from areas with good production to the short-supply areas, generally along east-west lines.

It is hoped that this brief review of the development and present capabilities of the U.S. soybean seed industry has served to focus attention on the opportunities as well as the problems in establishing soybean seed production and supply operations in the developing countries, especially those in the subtropical and tropical zones.

ATTRIBUTES OF SEED QUALITY

Seed quality in soybeans encompasses several important attributes:

1. *Genetic purity*--cultivar purity is important from the standpoint of both total performance and uniformity, especially uniformity of maturity.
2. *Physical purity*--soybean seed should contain a minimum amount of inert material and should not be contaminated with seed of objectionable weeds and other crops.
3. *Germination*--high quality seed should germinate 85 percent or better.
4. *Vigor*--the germinable seed in a lot should be vigorous enough to emerge rapidly and uniformly under a broad spectrum of seed bed conditions and to develop into rapidly growing, productive plants.

Although the most chronic and difficult seed quality problems in soybeans relate to germinability and vigor, serious problems can also arise in connection with cultivar and physical purity. Aspects of soybean seed production connected with maintenance of cultivar purity are briefly discussed below.

MAINTENANCE OF CULTIVAR PURITY

Cultivar purity in soybeans is maintained through systematic seed multiplication and a rigorous in-company or in-department quality control program, or participation in the multiplication and quality control system of a seed certifying agency.

Certification procedures (9) designed to maintain cultivar purity and other quality standards during multiplication/production and processing of soybean seed include:

(a) Limitation on generations--multiplication of soybean cultivars is limited to two generations beyond the foundation seed generation, viz., registered class seed, which is the progeny of foundation seed, and certified class seed, which is the progeny of registered or foundation seed.

(b) Control of seed source--the seed used to plant each seed crop for certification must be of the proper class, e.g., registered class seed must be produced from registered or foundation seed.

(c) Land history--soybean seed cannot be produced on land on which the previous crop was another cultivar of soybeans, or the same cultivar but not certified, unless the cultivar planted can be easily distinguished from the one grown the previous season. This is to prevent cultivar contamination from volunteer plants.

(d) Isolation--soybeans are self-pollinated; nevertheless, fields of different cultivars of soybeans must be adequately separated (minimum of 3 to 4 m) to prevent mechanical mixtures.

(e) Field standards--soybeans subject to certification are field inspected at least once--usually at maturity--to determine that the ratio of plants of other cultivars to those of the cultivar certified does not exceed established standards (Fig. 1, 2).

(f) Cleanliness of equipment and facilities--threshing equipment and floors, drying facilities, bulk storage units, conveyors and cleaning machines must be thoroughly cleaned before use and between any change in cultivar. Selection of equipment for ease of cleaning, therefore, is an important consideration in design of seed processing facilities.

(g) Seed standards--after processing and packaging, certified class seed must not contain inert matter in excess of 2 percent, seed of other varieties in excess of 0.5 percent, and seed of objectionable weeds in excess of established limits. Minimum germination is usually 80 percent.

The foregoing are the minimum standards adopted by the Association of Official Seed Certifying Agencies. Individual country seed certification agencies may and do have more rigorous regulations and higher standards.

FACTORS AFFECTING GERMINATION, VIGOR, AND STORABILITY

The sources of germination and vigor problems that cause difficulties in soybean seed production and supply are diverse: inexperience of the many "new" producers; compromises between quantity and quality that are usually resolved in favor of quantity; over-extension of production beyond harvesting, bulk storage, and processing capacity; unfavorable weather during harvest period, and so on. The basic and most important source of seed quality problems in soybeans, however, and the one which directly or indirectly influences the occurrence and severity of nearly all other problems, resides within the soybean seed. The "modern" soybean is a marvelous packet of valuable chemical constituents, but as a reproductive unit it borders on being a failure.

Seed Development and Morphology

The structural and physiological delicacy of the soybean seed contributes in a major way to many germination and vigor problems. Some knowledge of seed development and morphology is essential, therefore, for understanding the complexity of factors involved in loss of germinability and vigor, and possible means of minimizing these losses.

Development of the soybean seed begins with fertilization (sexual). The two cotyledons and growing points are fully differentiated within the first 2 weeks. Dry weight of the developing seed increases slowly until about 20 to 30 days after flowering, depending on date of flowering (2), while moisture content (w.b.) slowly decreases from about 90 to 80 percent (Fig. 3, Lee cultivar). (Date of flowering--fertilization--has a pronounced effect on rate of seed development in a determinate variety such as Lee. Seeds from late season flowers develop much more rapidly than those from early season blooms. Seed set late in the season, therefore, "catches up" to that set earlier as the season progresses.) Beginning about 25 to 35 days after flowering, dry matter begins to accumulate rapidly in the seed reaching a maximum at 65 to 75 days. Thereafter, dry weight tends to remain constant or to decrease slightly (sometimes substantially when the seed is severely weathered prior to harvest). During the period of rapid dry matter accumulation, seed moisture content decreases rather slowly to 40 to 50 percent at the time maximum dry weight is attained. Under good field drying conditions seed moisture content then decreases from 40 to 50 percent to 15 to 18 percent in about one week.

Soybean seeds are physiologically mature at the time maximum dry weight is reached (40 to 50 percent moisture content). At this stage, germinability and vigor of the seed are highest even though the seed first becomes capable of germination when only about one-third of the dry weight has been accumulated.

Fig. 1. Above, effective field inspection of seed crops requires expert knowledge of characteristics of cultivars and weeds. Four-row plots of all cultivars grown in an area such as illustrated above provide an excellent vehicle for training and reviewing of inspectors.

Fig. 2. Careful and rigorous roguing of seed production fields is necessary to maintain cultivar purity.

The mature soybean seed is generally spherical in shape and has a relatively thin seed coat (Fig. 4). The hilum, point of attachment of the seed in the pod, is linear to elliptic in shape and located on the ventral face of the seed coat. It may be variously pigmented. The endosperm is represented only by a thin layer of cells immediately beneath the seed coat. The remainder of the interior of the seed is occupied by the embryo, which consists of a short radicle-hypocotyl axis, two fleshy cotyledons (lateral organs), and a well-developed plumule-growing point with two leaves, which is terminal on the radicle-hypocotyl axis and between the cotyledons.

The short radicle-hypocotyl axis is curved so that it lies against the basal margins of the cotyledons with its tip pointed in the same direction as the apices of the cotyledons. The position of the radicle-hypocotyl axis and the delicacy of the seed covering which is its only protection, makes the seed especially vulnerable to injury by mechanical abuse from any source--harvesting, conveying, processing, and so on. Since the radicle-hypocotyl axis is essential for normal germination, any substantial damage to it can be disastrous from the standpoint of seed quality.

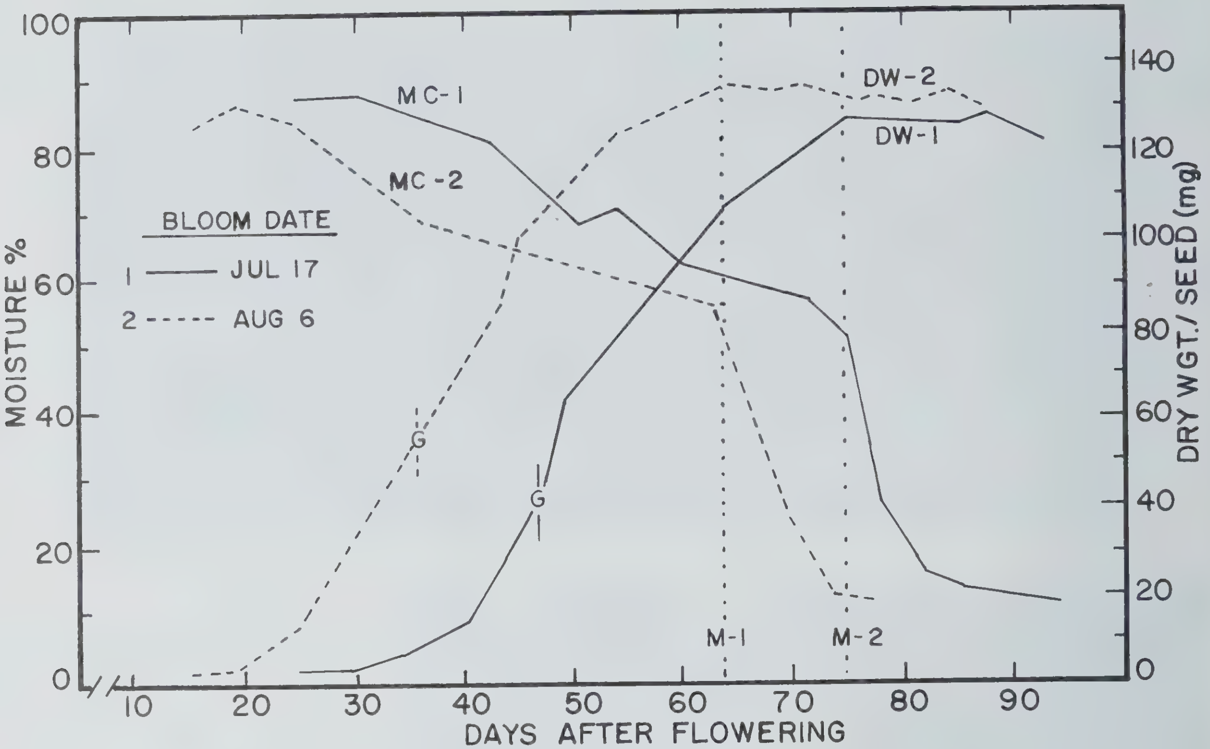

Fig. 3. Moisture content and dry weight changes in soybean seed during maturation. MC, moisture content (w.b.); DW, dry weight per seed; G, 50 percent of seed capable of germination; M-1, physiological maturity of seed set from July 17 flowers; M-2, physiological maturity of seed set from August 6 flowers. From Andrews (2).

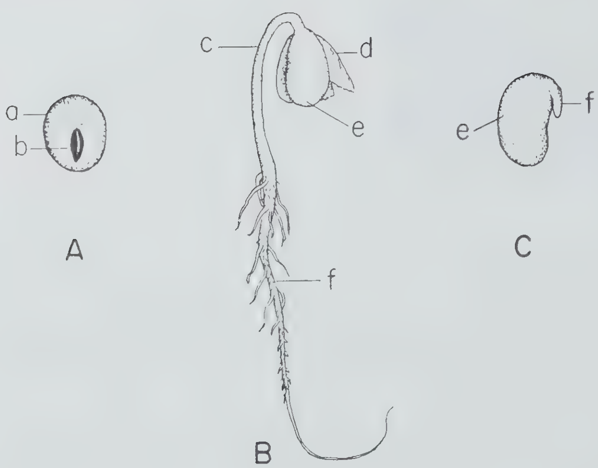

Fig. 4. Seed and seedling structure in soybeans. A, mature seed; B, seedling; C, embryo; a, seed coat; b, hilum; c, hypocotyl; d, plumule; e, cotyledon; f, primary root (radicle). Drawing from Delouche et al. (25).

Field Environment

The quality of soybean seed is very much affected by climatic conditions from the time the seed first drops below 25 percent in moisture during the postmaturation drying phase until the seed is harvested. Since the seeds are physiologically mature, they are in effect "stored" in the field during this period (17, 24).

Frequent or prolonged precipitation during the postmaturation, preharvest period results in alternate wetting and drying of the seed in the pod and severe deterioration. The dates in Table 1 are illustrative of the effects of adverse climatic conditions on moisture content and germination of soybean seed while it is still on the plant. After reaching "field maturity", i.e., harvestable stage on about September 20, Hill soybean seed fluctuated in moisture content from 11 to 20 percent depending on rainfall, while germination dropped to below 80 percent by October 6 and then further to 37 percent by November 3. The Bragg cultivar, which reached field maturity around October 23 or approximately one month later than Hill, also fluctuated widely in moisture content under the influence of rainfall, but loss of germinability was not nearly so severe. Bragg seed harvested on December 12 still germinated above 80 percent (Fig. 5).

The much greater reduction in germination of the Hill soybean seed as compared to seed of Bragg, even though subjected to fewer rains, can be attributed to the generally warmer temperatures in the area during the Hill weathering period. The effects of weathering on seed quality increase in severity as temperature increases. For this reason, germination problems of early maturing cultivars are more frequent and severe than for late maturing cultivars in temperate climates (19, 45).

The soybean seed producer cannot control climatic conditions during the harvest period but he can take several steps to limit both the extent and severity of weathering. Soybean seed should be harvested when it reaches field maturity (14 to 15 percent moisture) unless rainfall interferes. When rains delay harvest, seed producers equipped with adequate drying facilities can take advantage of any break in the weather. They need not delay harvest until moisture content drops back down to 14 percent or less.

Reduced seed quality in soybeans has also been associated with environmental conditions just the opposite of those discussed above. Hot, dry weather during harvest adversely affects both the physical and physiological quality of soybean seed (32, 33, 37).

Some efforts are being made to improve seed quality in soybeans through development of lines resistant to weathering and other environmental stresses during the maturation period (33, 34, 35, 57).

Harvesting and Threshing

In terms of seed quality, the harvesting and threshing process is probably the most critical phase of the over-all soybean seed production-processing operation. It is critical in three respects. First, improper cleaning of the combine and incautious operation are major sources of cultivar contamination. Second, timeliness of harvest is most important in minimizing field deterioration as mentioned above. Finally, mechanical abuse during harvesting and threshing operations is the most important cause of injury to soybean seed, commonly referred to as mechanical damage.

The adverse effects of inclement weather during the harvest period on seed quality have been discussed. It does not follow, however, that good drying weather completely eliminates quality problems. The opposite is all too frequently the case. Seed moisture content decreases rapidly when good drying weather prevails during the "normal" harvest time, or following a rainy period. In such cases, seed moisture may drop to 10 percent or less before harvest and threshing can begin or are completed. Very often the result is substantial seed injury even though harvest is done as carefully as possible.

Soybean seed becomes very brittle and susceptible to injury from mechanical forces when moisture content drops below 12 percent. Germination of soybean seed at 12 percent moisture or less can be immediately reduced as much as 10 percent by the force of an impact resulting from a 5 ft drop onto a metal surface, while a 20 ft drop onto the same surface has no immediate or latent effect on seed at 14 percent moisture content. The mechanical forces generated in the threshing section of a combine (Fig. 6, 7) and in certain types of conveyors are much greater than those resulting from a 5 ft or even a 10 ft drop (41, 44, 55).

Table 1. Effect of weathering on moisture content and germination of seed of the Hill and Bragg soybean varieties (25).

Date of harvest[a]	Hill: Moisture content (%)	Hill: Germination (%)	Bragg: Moisture content (%)	Bragg: Germination (%)
9/15	26	96		
9/22	13	97		
9/29+[b]	17	90		
10/6+	20	78		
10/13	11	76	26	98
10/20+	19	71	18	98
10/27	12	53	13	93
11/3+	14	37	14	92
11/10			12	92
11/17+			20	89
11/24+			13	86
12/1			15	87
12/8			11	84
12/15+			14	84

a/ Seed hand harvested and threshed, then cleaned with hand screens and aspirator before germination test.

b/ Date followed by + indicates one or more rains during preceding week.

Fig. 5. Weathering before harvest has a highly adverse effect on seed quality in soybeans. Above, periodic "sprinkling" treatments are being applied in an attempt to quantify the relationship between frequency and extent of precipitation, temperature, and degree of seed deterioration.

Fig. 6. Soybean seed can be severely injured during harvest when seed moisture content is low and the combine is not properly adjusted and operated.

Fig. 7. Soybean seed can be injured as badly with small plot threshers (below) as with large combine harvesters.

The most favorable seed moisture content for harvest of soybeans is a matter of some controversy. Available evidence (11, 19, 32, 41, 44, 46, 49, 52) suggests, however, that there is a rather narrow range of seed moisture contents that are optimal for harvest, between about 13 and 15 percent. Seed cracking and splitting increases sharply as moisture content decreases below 13 percent, while seed bruising and other less visible--but not less detrimental--injuries increase at moisture contents above 15 percent.

A few rules for harvesting as related to maintenance of seed quality are advanced below.

1. Weed free, uniform stands facilitate adjustments of harvesters to minimize seed damage.

2. Commence harvesting when seed moisture content first drops below about 15 percent.

3. Combine at uniform ground speed.

4. Adjust clearance and cylinder speed so that complete threshing is achieved--but not higher.

5. When hand threshing is the practice, avoid strong forces, such as driving a tractor over unthreshed plants.

6. Check threshed seed periodically to determine extent of seed damage.

7. Weathering reduces resistance of seed to cracking and splitting; therefore, thresh weathered seed at higher moisture content 14 to 15 percent and avoid strong mechanical forces.

Handling, Bulk Storage, Aeration and Drying

Handling and conveying. All handling and conveying operations must be accomplished as gently as possible to minimize seed damage. For this reason, use of inclined augers for loading seed into bulk storage bins is not recommended. Loading of bins is best accomplished by "belt-veyors" or via the typical vibro-dump pit, belt-bucket, or continuous bucket elevator, horizontal drag flight, or belt conveyor, gravity spouting system (46, 55) (Fig. 8). The use of "dead boxes" in the longer gravity spout runs, to decrease velocity of seed flow and to absorb impact at points of directional change, and a "bean ladder" or spiral "letdown" inside the bin, contribute greatly to the high quality soybean seed operation. Unloading of storage bins and conveying of seed to the processing plant are usually accomplished with short, horizontal unloading augers feeding onto or into a drag flight or belt conveyor.

Bulk storage and aeration. After harvest, soybean seed is usually stored in metal bins equipped for aeration or drying, or both, until the seed is processed and packaged (Fig. 9). The period in bulk storage ranges from a few weeks to about 6 months. Drastic reductions in germination and vigor can occur during the bulk storage period when seed moisture content is above 13 percent and the seed is not properly aerated or dried as necessary (12, 15, 19, 28, 39, 43, 46).

Aeration is usually adequate for conditioning and maintenance of seed viability at 13 percent moisture or less. Aeration equalizes temperature within the seed mass, prevents moisture migration, cools the seed to ambient temperature, and can reduce seed moisture content by 1 to 1.5 percent with higher air flow rates. Air flow rates of 0.1 to 1.0 cu ft of air per min (CFM) per bu are used for aeration. An air flow rate of near 1.0 CFM/bu is necessary to reduce seed moisture content by 1.0 to 1.5 percent as mentioned above. Aeration is best controlled with a humidistat set to cut off the fan whenever ambient relative humidity rises above 65 to 70 percent, which is in equilibrium with a seed moisture content of about 12.5 percent. The aeration system is turned off after the seed mass has cooled down and moisture content has stabilized. Thereafter, the system is activated periodically to prevent temperature stratification and moisture migration in the bin.

Drying. Soybean seed harvested above 14 percent moisture must be dried to 13 percent or less to maintain viability in bulk storage (6, 19). Natural air drying at flow rates of 3 to 5 CFM/bu are adequate for drying seed up to about 16 percent moisture. For seed at moisture contents above 16 percent, supplemental heat and higher air flow rates (6 to 9 CFM/bu) are usually necessary for effective drying. Depth of the seed for drying should not exceed 4 ft, and temperature of the drying air should not exceed about 30°C (Fig. 10).

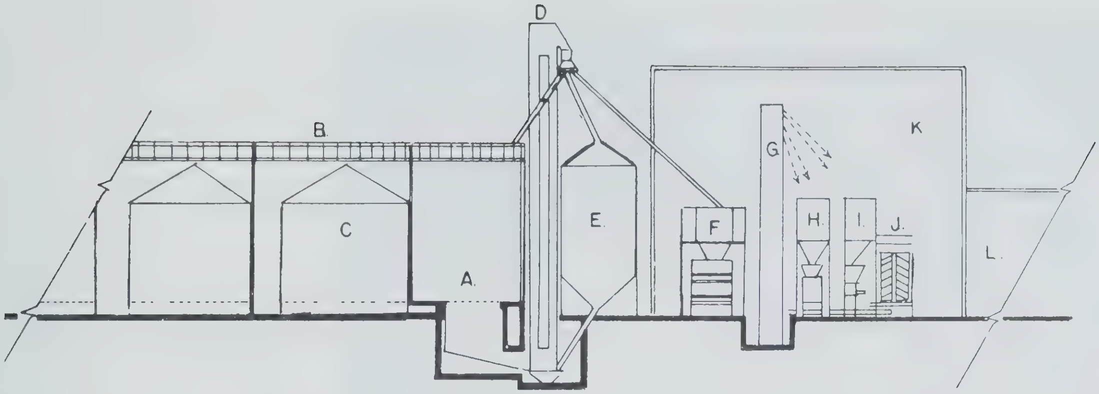

Fig. 8. Side elevation (nonscaled) of a typical soybean seed facility. A, receiving area and dump pit; B, drag flight conveyor for loading bins; C, aeration-bulk storage bin; D, main receiving elevator; E, holding bin; F, surge bin and air screen cleaner; G, four-way continuous bucket elevator; H, surge bin and treater; I, surge bin and bagger-weigher; J, spiral separators; K, processing building; L, bagged seed storage building.

Fig. 9. Typical bulk storage bins used for storage and aeration of soybean seed.

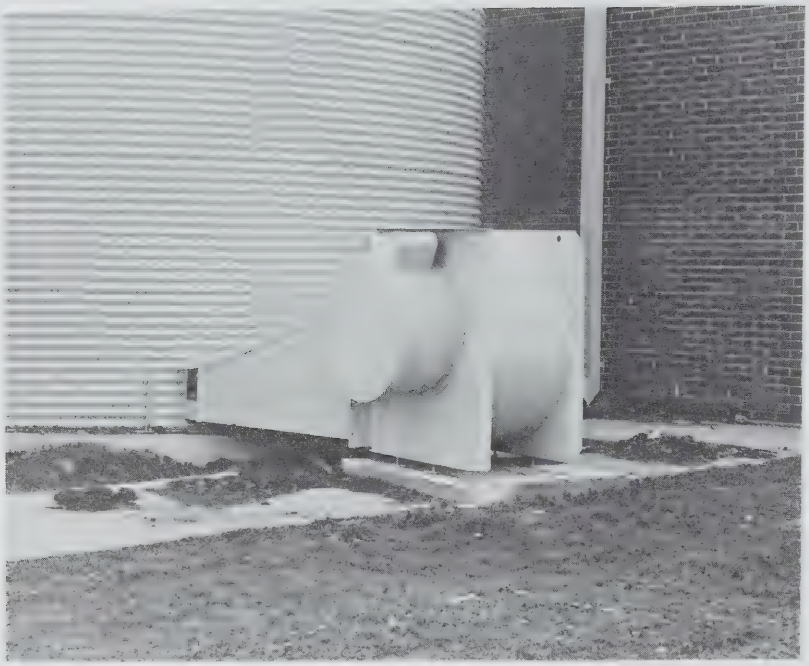

Fig. 10. Heater-fan unit attached to plenum beneath storage bin for drying of soybean seed with supplemental heat.

Processing

Soybean seed moves from the bulk storage bins through the cleaning plant and into the packaged seed storage warehouse as the processing season progresses (Fig. 8). Basic cleaning is accomplished with an air and screen machine (19, 56). The air and screen machine removes fragments of pods, stems and seed, weed seed, immature seed, and other contaminants that are lighter, smaller, and larger than mature, intact soybean seed. Basic cleaning can increase germination percentage by a few points through removal of badly damaged, immature, and rotten (light weight) seed. In most cases basic cleaning is all that is necessary to prepare the seed for packaging and marketing.

Soybean seed is not difficult to clean. Most cleaning problems can be traced to attempts to "squeeze" too much capacity from the air and screen cleaner and other cleaners. It should also be pointed out that the cleaning machines, surge bins, and conveyors in the processing plant are potential sources of cultivar contamination. Therefore, the entire processing plant should be thoroughly cleaned at the beginning of the processing season and between any change in cultivar or seed kind during the processing season.

Treatment of soybean seed with a fungicide is beneficial, particularly when germination is less than 80 percent and the seed is infested with a disease such as pod and stem blight (7, 10). Only a relatively small proportion of soybean seed marketed, however, is treated because the risk of financial loss to the seedsman is too great. Once seed is treated with a fungicide it can only be used for planting purposes. Thus, seed that is not marketed for any reason, e.g., drop in germination below market standard, slow market, and so on, cannot be sold as grain; it must be dumped. For this reason, when soybean seed is treated with a seed protectant, the chemical is most frequently applied in the planter box.

The final step in processing is packaging. Soybean seed can be packaged in multiwall paper bags, woven plastic bags, or burlap or cotton cloth bags.

Storage

The storage period for soybean seed begins at harvest (actually at the time seed reaches physiological maturity prior to harvest) and usually ends at planting time the following season. This period can be divided into two phases: the bulk seed storage phase, and the packaged seed storage phase. The former was discussed to some extent in connection with handling, aeration, and drying.

The longevity of seed in storage is influenced by four major factors: (a) inheritance of the species; (b) quality of the seed at the time it enters storage; (c) temperature of the storage environment; and (d) the moisture content of the seed or ambient relative humidity (17, 18, 19, 24, 28, 36).

Species. Soybean seed is inherently short-lived as compared to other major crop species (24). Under climatic conditions in the southeastern United States, germination percentage of the "average" soybean seed lot is maintained through May-June of the year following harvest (October-November), after which it begins to decrease, sometimes rather abruptly. Thus, germinability of soybean seed in the Southeast is just barely maintained through the first planting season following harvest. Seeds of corn, sorghum, cotton, and wheat, on the other hand, usually maintain germination through the second planting season following harvest, although seed vigor is often substantially reduced (Table 2).

In subtropical and tropical areas, the poor storability of soybean seed is a major constraint on production (24). The seed often drops in germination to the extent that it is worthless for planting within 2 to 3 months after harvest.

Quality of seed entering storage. The storability of seed is very much influenced by the degree to which the seed has deteriorated prior to storage. Soybean seed subjected to weathering before harvest, severely damaged during combining, and/or inadequately aerated during bulk storage does not store well even though it germinates moderately well at time of packaging (18, 19, 21, 28). Storage responses of two groups (A and B) of four lots each of soybean seed are given in Table 2 (20). The four seed lots of the A group were high in germination and vigor. The group B lots were considerably deteriorated before storage as a result of weathering and mechanical abuse. At the beginning of packaged seed storage in December 1968, average germination of the B lots was only 8 percent lower than that of the A lots. In the same storage environment, the difference in germination between the A and B lots increased to 29 percent by May 1969 (6 mos), 63 percent by August, and 71 percent by May 1970 (71 percent for A lots as compared to 0 percent for B lots).

Table 2. Comparison of germination percentages of different seed kinds during storage under ambient conditions, Mississippi State University, 1968-1970(20).

Kind of seed	Time in storage (mo)[a/]					
	0	6	9	12	18	24
Soybeans A	90[b/]	91	86	84	71	33
B	82	62	23	15	0	0
Corn	98	98	99	98	97	90
Wheat	94	95	92	94	90	82
Cotton	87	83	86	86	83	74
Sorghum	94	91	95	92	90	82

a/ Period of storage: 12/68 through 11/70.

b/ Each datum represents average germination percentage of four "commercial" seed lots of each kind.

Temperature and moisture content. Seeds are hygroscopic. They absorb moisture from the atmosphere or lose moisture to it until the vapor pressures of seed and atmosphere reach equilibrium. Since the vapor pressure of atmospheric moisture at a specific temperature and pressure is a direct function of the degree of saturation or relative humidity, the various levels of seed attain characteristic moisture contents when exposed to different levels of relative humidity for sufficiently long periods of time. The seed moisture contents attained under these conditions are variously referred to as the equilibrium moisture contents, or hygroscopic equilibria. At 25°C, moisture contents of soybean seed in equilibrium with various levels of relative humidity are:

Rel. humidity (%):	15	30	45	60	75	90
Moisture (%):	4.3	6.5	7.4	9.3	13.1	18.1

Seed storage studies or practical storage operations most often emphasize the controlling influence of relative humidity on seed moisture content. The hygroscopic equilibrium between seed and ambient relative humidity, however, is a two-way street. During the critical days following harvest when seed is in bulk storage and during any phase of storage involving moisture-vapor-proof packages, the controlling influence of seed moisture content on relative humidity of the immediate environment of the seed is paramount.

The relative humidity within a mass of soybean seed harvested at 16 percent moisture and loaded into a bulk storage bin is above 80 percent. And, it will remain at this level for a considerable period regardless of the outside relative humidity unless the seed is aerated. The relative humidity inside a 10 mil plastic bag of seed is similarly determined by the moisture content of the seed rather than vice versa.

It is important to consider both sides of the seed-moisture-vapor equilibrium because relative humidity within the seed mass has effects other than on seed moisture content. The growth and reproduction of storage fungi, which contribute to quality losses in seed and grain, are highly dependent on relative humidity within the seed mass (15). The more important storage fungi cannot grow and reproduce in seed or grain in equilibrium with a relative humidity less than 65 to 70 percent (12.5 percent moisture content in the case of soybeans). Activity of storage insects also drops sharply at relative humidities below 50 percent.

The temperature of the storage environment and within the seed mass also has a profound effect on maintenance of seed quality (18, 28, 36). In most instances temperature and seed moisture content (or relative humidity) interact closely in their effects on longevity of seed. High moisture content seed (e.g., 15 to 18 percent) can be stored for a year or more at a temperature of 10°C or less, while low moisture seed (9 percent or less) can withstand temperatures in the range 30° to 35°C for the same period without substantial loss of germination.

The classic study of Toole and Toole (54) illustrates very well the effect of temperature and seed moisture content on the longevity of soybean seed in storage (Table 3). Germination of 9.4 percent moisture seed was maintained above 80 percent for more than 10 years at 10°C, for 5 years at 20°C, and one year at 30°C. In contrast, germination of 13.9 percent moisture seed decreased below 90 percent within 5 years at 10°C, 2 years at 20°C, and 0.5 year at 30°C.

Table 3. Effect of seed moisture content and temperature on germination percentage of soybean seed during storage (54).

Moisture (%)	Temperature (°C)	Years in storage (approx.)						
		0.5	1	2	3	4	5	10
9.4	10	93	95	98	93	99	92	94
	20	97	99	96	94	89	90	0
	30	96	87	0				
13.9	10	95	98	96	92	88	49	0
	20	98	93	0				
	30	0						

In a more recent study conducted by Delouche and Baskin (20) in cooperation with a seed producer at Windfall, Indiana, soybean seed packaged at 9 percent moisture in either multi-wall paper or 7 mil polyethylene bags maintained germination through 40 months in a "cool" but unconditioned warehouse. Seed vigor, however, was substantially reduced after 24 months (Fig. 11).

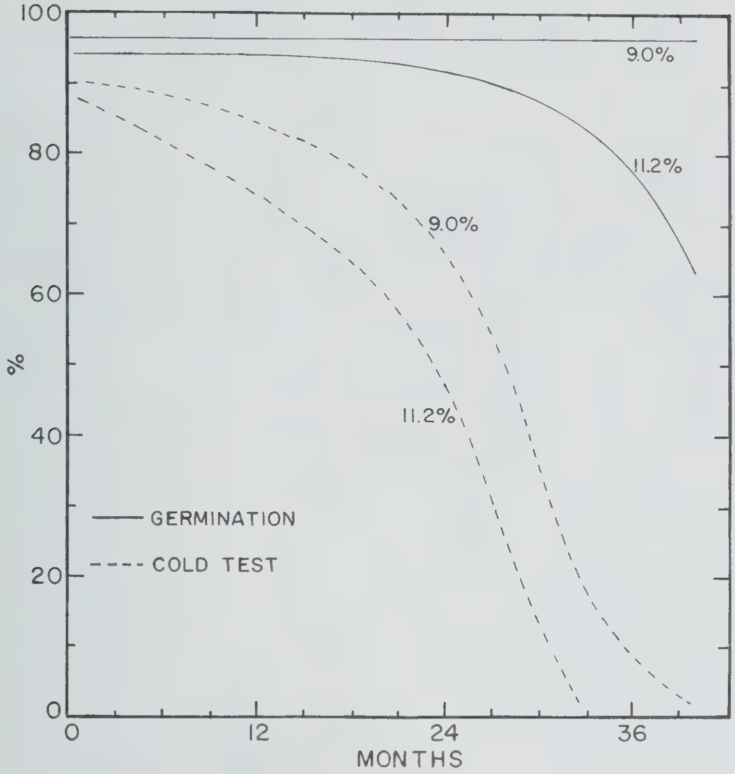

Fig. 11. Germination and cold test percentages of Clark soybean seed packaged in 3-ply multi-wall paper bags during storage for 40 months in an unconditioned warehouse at Windfall, Ind., U.S.A. (20).

For maintenance of both germination and vigor from harvest to planting (about 8 to 9 months) in temperate climates, soybean seed should be rapidly and properly conditioned to 12 to 13 percent moisture content after harvest, and stored over the winter in a dry, ventilated storehouse. In subtropical and tropical areas where the average annual temperature may be as high as 25°C, some type of moderately conditioned storage is usually necessary to maintain soybean seed quality. Air-conditioning a well-constructed storeroom so that temperature is maintained at 20° to 22°C or less, and relative humidity at 60 percent or less will usually maintain the quality of soybean seed for 8 to 9 months provided the seed is of reasonably good quality when placed in storage (Fig. 12).

One alternative to air-conditioned storage of soybean seed in subtropical and tropical areas is to condition the seed to about 9 percent moisture and then package it in moisture-vapor-proof packages such as 10 mil thick polyethylene bags. The plastic bags should be heat-sealed and precautions should be taken to prevent puncturing. Considering the long-term economics of soybean seed storage and the effectiveness of the two systems, i.e., air-conditioning or moisture-vapor-proof packaging, air-conditioning is the preferred method.

Soybean seed storage problems can also be lessened in subtropical and tropical areas by concentrating seed production in the "minor" rainy season or in the dry season under irrigation. Seed yield may be less but the storage period will be reduced from 8 to 9 months to 2 to 3 months. Air-conditioned storage usually is not necessary for 2 to 3 months' storage provided the seed is dried to 13 percent moisture or less.

For long-term maintenance (5 to 8 yrs) of valuable seed material such as genetic lines, cultivar collections, limited quantities of breeder seed, and the like, a highly conditioned storeroom is essential. The storeroom should be well constructed so that transmission of moisture-vapor through the walls is minimal. It should be insulated and equipped with a refrigeration-dehumidification system capable of maintaining conditions of about 10°C and 50 percent relative humidity (Fig. 13).

CONDITIONED SEED STORAGE WAREHOUSE, SAN PEDRO SULA, HONDURAS

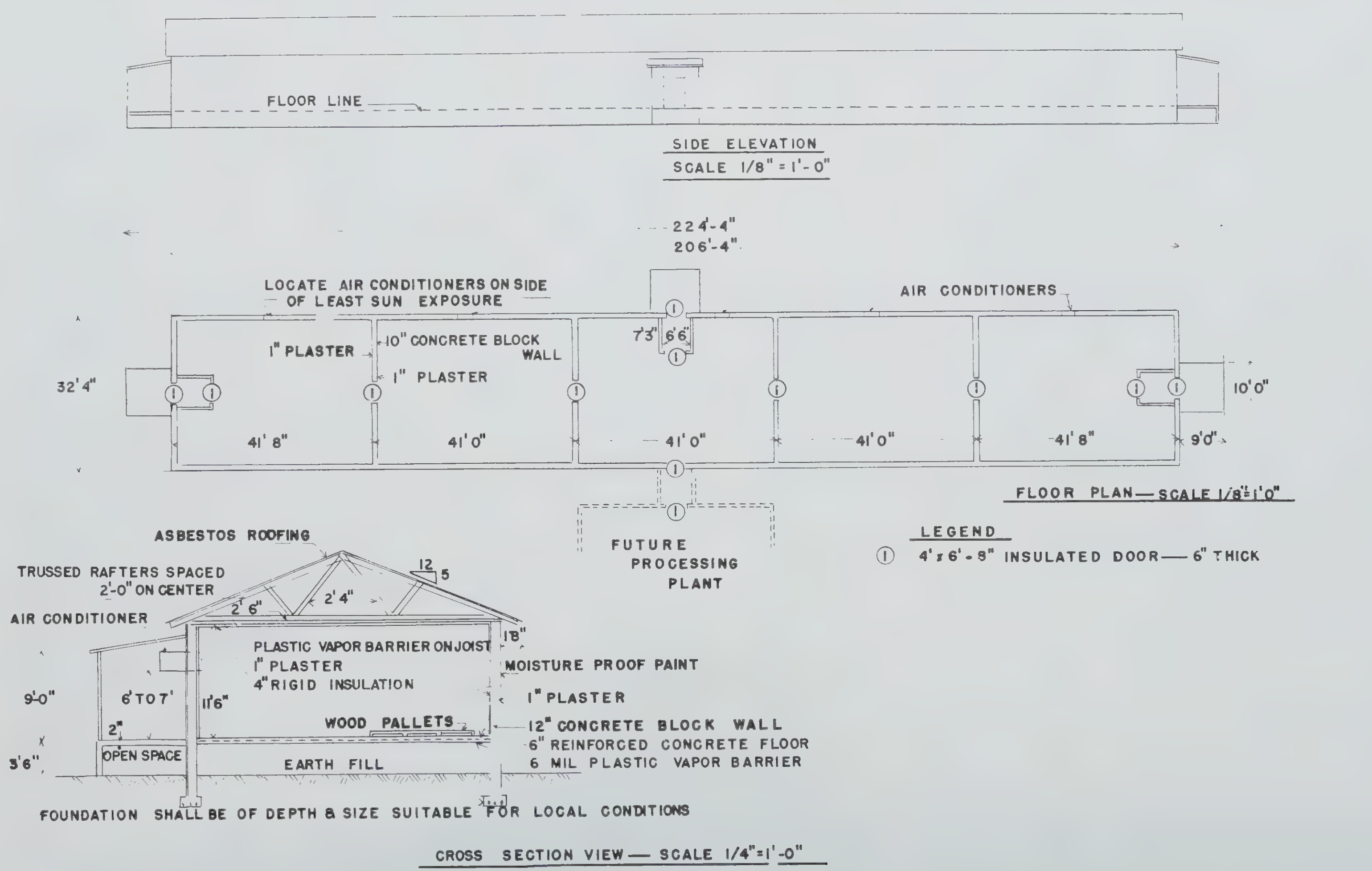

Fig. 12. "Air-conditioned" seed storage facilities designed for the Government of Honduras. Conditions of about $23^{o}C$ and 55 percent relative humidity are maintained in the storerooms with conventional air-conditioning units and condensation-type dehumidifiers.

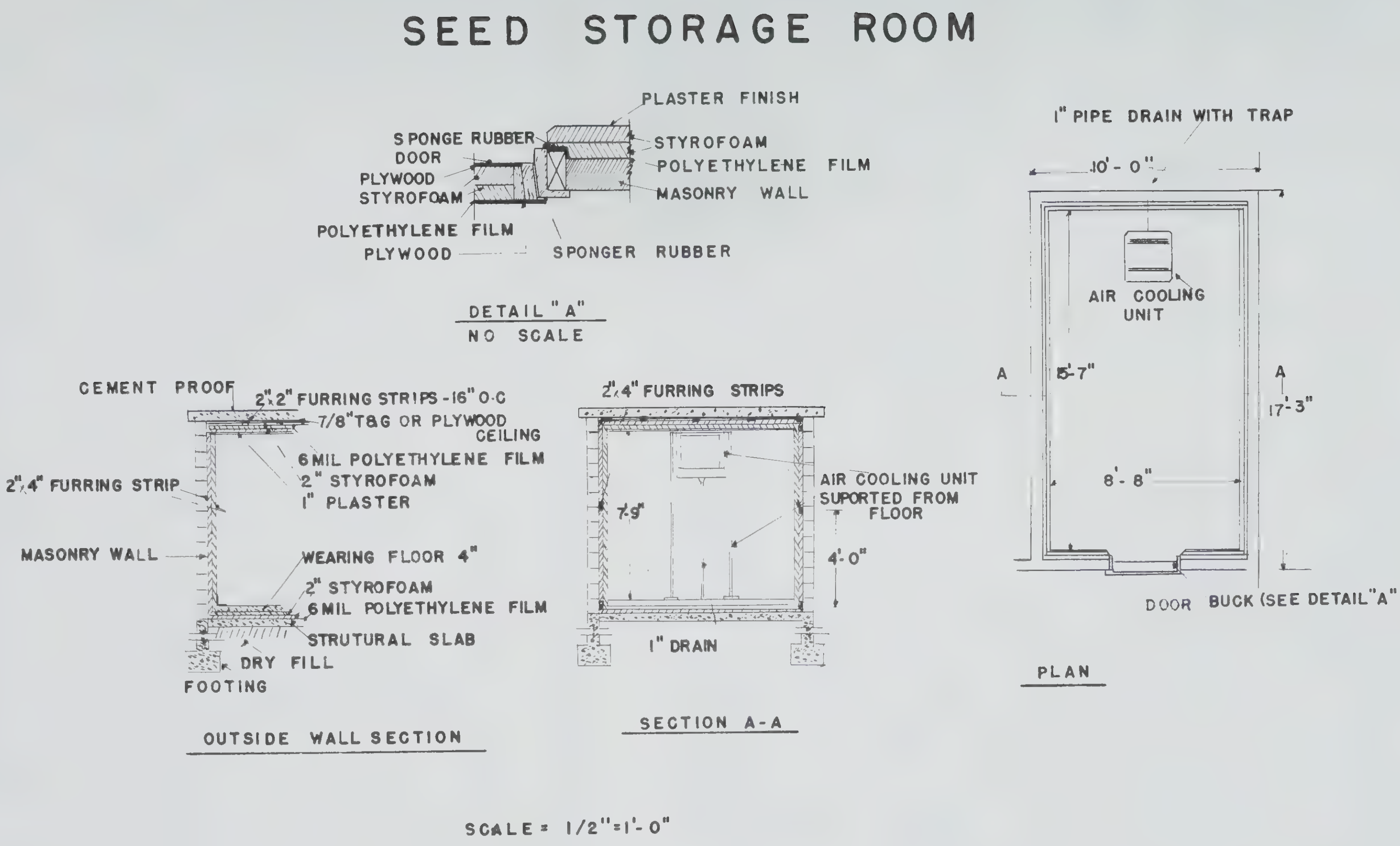

Fig. 13. Details of construction, insulation, and moisture-vapor proofing of cold storage room for long-term storage of seed. Cooling and dehumidification are best accomplished with a refrigeration system of adequate capacity combined with a desiccant dehumidifier.

Evaluation of Seed Quality

The quality of soybean seed is routinely evaluated by standard test procedures (8). These procedures include a purity analysis, germination test, and usually a moisture test.

Purity analysis. In the purity analysis the percentage by weight of pure seed, other crop seed (including seed of other varieties as can be identified), weed seed, and inert matter is determined. Modern soybean varieties can seldom be positively identified by seed characters alone. Often, however, it is possible to determine that a particular seed is not of the variety specified. Although various seed and seedling characters are useful in determining trueness-to-cultivar in soybeans, field grow-out tests generally are necessary to accurately assess cultivar purity.

Germination test. The percentage by number of seeds capable of producing "normal" seedlings is determined. The germination test has serious limitations as a measure of the stand and crop producing potential of soybean seed, as will be discussed below.

Moisture test. The moisture content of the seed, wet weight basis, is determined, usually with an electric moisture meter. Moisture content data are very important from harvest through marketing.

Germination, Deterioration, and Vigor

The stand and plant producing potential of soybean seed, and other kinds of seed as well, is most commonly evaluated by a germination test. Exacting procedures for determining the germination percentage of seed lots have been developed and perfected over the past 100 years and are codified in the Rules for Testing Seed (8). In many ways, the standard germination test appears to admirably serve the needs and interests of seed analysts, seed control officials, and seed producers. The germination test, however, has several deficiencies which should be recognized. The deficiencies of the germination test as a measure of the plant producing potential of seed stem from two main sources: the overall philosophy of germination testing, and the nature of seed deterioration.

Procedures for germination testing of seed have been established on the basis of the "optimization" principle, i.e., test conditions are optimized so that maximum germination percentages are obtained. Thus, germination tests are made largely on "artificial," standardized, essentially sterile media, in humidified, temperature controlled germinators for periods sufficiently long to permit even the weakest seed to make its debut as a normal seedling.

It has not been well established that the performance potential of a seed is progressively impaired through deteriorative processes that inevitably occur over time--a few minutes or many years. The identity and sequence of the deteriorative changes--or the manifestations of change--that occur in a seed as it dies are known only in a general way. The available evidence, however, suggests that during deterioration essential biological systems and mechanisms are progressively impaired so that the consequences, in terms of germination and subsequent growth and development, become progressively more serious (4, 17, 21, 29, 30, 38, 53).

Membrane degradation and loss of permeability control occur at an early stage during seed deterioration (1, 14, 21). Energy yielding and biosynthetic processes are then impaired with a resulting decrease in rates of respiration, transfer of dry matter from supporting tissues to the embryonic axis, germination, and early seedling growth (21, 29, 38, 58, 59). At about this stage in the progress of deterioration, the seed appears to lose much of its natural resistance to environmental stresses and seed rotting microorganisms.

Reduced rate of germination and early seedling growth are subsequently reflected in a decreased rate of plant growth, delayed flowering and maturity, and reduced yield. As deterioration progresses further, the seed fails to emerge from the seed bed even under rather favorable conditions. Finally, it loses its capacity to "germinate" even in the optimum environment of the germinator. Because the seeds within a lot are not uniform in physiological quality and they become progressively more so as deterioration advances, irregular and non-uniform emergence, plant growth, development, and maturation are other important consequences of deterioration that precede the 0 percent germination stage.

The germination test is an insensitive and misleading measure of seed quality because it focuses primarily on the final, albeit most disastrous, consequences of deterioration, and does not adequately take into account the very substantial loss in

performance potential that can and does occur before the germinative capacity is lost. Yet, the lesser consequences of seed deterioration, such as reduced resistance to environmental stresses, decreased seedling and plant growth rate, and so on, have become of greatest importance. Few seedsmen knowingly sell, and few farmers will knowingly plant, dead or low germination seed. Both seedsmen and farmers, however, are damaged all too frequently because seed of "good" germination fails to perform satisfactorily when planted in the field. Seed that germinates moderately well but has low stand establishment potential is said to be low in vigor.

Many attempts have been made to rigorously define the term vigor as applied to seed. The result is a multitude of concepts and definitions all of which have some degree of validity and applicability, and which collectively cover the subject rather thoroughly (23, 38, 40, 50, 51, 59). While space does not permit examination of the various definitions and concepts of seed vigor, it should be pointed out that vigor, as an attribute of quality, is meaningful only in reference to germinable seed. A nongerminable seed has zero performance potential, hence, no vigor. Vigor tests, therefore, supplement the standard germination test. The germination test establishes the percentage of germinable seed in a population or lot, while a vigor test evaluates the performance potential of the germinable seed. Vigor tests, of course, also assay the extent of deterioration of seeds within a population which really determines their performance potential. Thus, vigor and degree of deterioration are essentially the positive and negative aspects, respectively, of performance potential.

A variety of vigor tests have been developed but only a few have found application in a more or less routine manner in seed quality evaluation and control programs (23, 38, 40, 50, 59). The more successful vigor tests evaluate response-reactions of individual seed which permits expression of test results as a percentage by number of seeds tested, much as in the germination test.

Byrd and Delouche (13, 14) compared the efficiency of several of the more widely used vigor tests with the germination test for evaluating the progress of deterioration during storage and the field emergence potential of soybean seed. They found that germination percentage was the least sensitive index of the progress of deterioration and reduction in emergence potential during storage (Fig. 14). Soybean seed stored in an environmentally controlled room at 30°C and 50 percent relative humidity did not significantly decrease in germination percentage until after 7 months. Accelerated aging and cold test responses, however, significantly decreased after 1 to 4 months' storage, as also did field emergence percentage.

Preliminary results from extensive studies being conducted by Andrews and Vaughan (5) with the objective of establishing a vigor rating system for soybean seed lots indicate that two vigor tests are especially promising for soybeans: the accelerated aging test, and the tetrazolium test interpreted for vigor.

Accelerated aging test. The accelerated aging test was developed for evaluating the storability of seed lots (21). Everson (26) and associates at the Iowa State University Seed Testing Laboratory have effectively used the test to determine the "carry-over" potential of soybean seed lots. For this purpose they used accelerated aging conditions of 40°C and 99 percent relative humidity for 30 h followed by a 7 day regular germination test.

It is not surprising that the accelerated aging test also has proven useful as a vigor test for evaulating the stand producing potential of seed. Storability, after all, is influenced by vigor or degree of deterioration just as is rate and percentage of emergence. In regard to soybean seed lots, accelerated aging under conditions of 40°C and 100 percent relative humidity for 48 h or for 72 h followed by regular germination test have produced results that correlate closely with field emergence.

Tetrazolium test. The tetrazolium test (TZ) is most widely used to rapidly estimate the germination percentage of seed lots. Procedures for use of the TZ test in this manner have been developed and published (25, 31). The TZ test is equally applicable for evaluating vigor of seed as has long been advocated by Moore (47, 48). When conducted by an experienced analyst, it is probably the most informative of all tests for evaluating the physiological quality of seed.

We use the classification system developed by Moore. Category 1 represents the most vigorous seed, category 2 the second most vigorous, and so on, through category 5 which represents the least vigorous of the germinable seed. Categories 6, 7, and 8, which encompass nongerminable seed, are usually not used in establishing a vigor rating but do provide useful

information regarding the progress of deterioration in the lot. The numbers of seed falling into categories 1 and 2, or 1, 2, and 3, are variously used to compute a germination or tetrazolium "energy" percentage, i.e., percentage of vigorous seed.

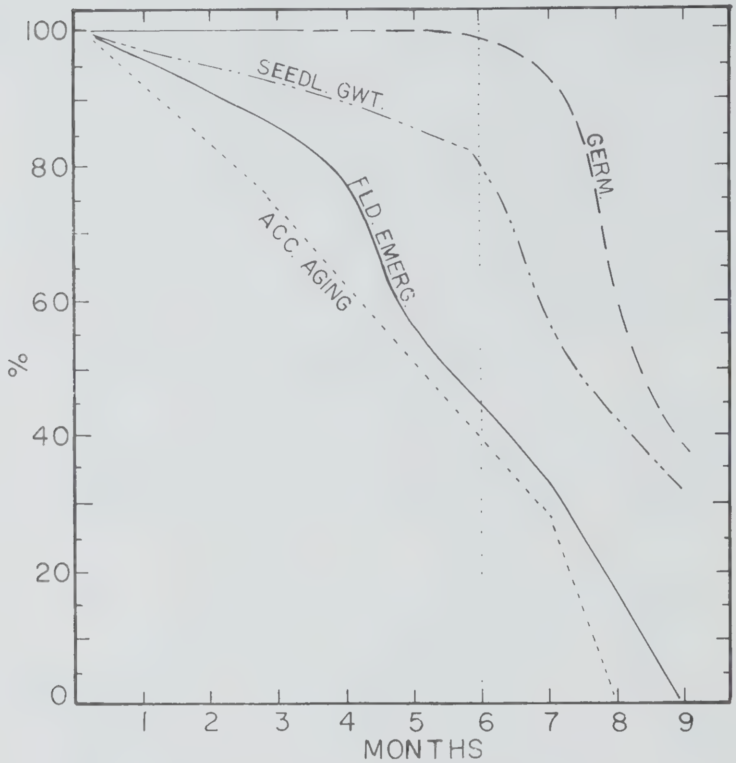

Fig. 14. Response-reactions of Lee 68 soybean seed during storage at 30°C and 50 percent relative humidity, relative to levels of responses at the beginning of storage, i.e., 0 months = 100 percent.

In our view, quality control programs for soybean seed should utilize at least one vigor test in addition to the regular germination test to assess seed quality. And, these should be conducted at least twice with the last test as close to the end of the storage period as possible.

SUMMARY

An effective, efficient seed production and supply system is necessary for extension of soybean production in all countries.

The most chronic seed quality problems in soybeans relate to germinability and vigor. Soybean seed is inherently short-lived and structurally weak as compared to other kinds of seed. Substantial losses in germinability and vigor are caused by hot, dry weather during seed maturation, weathering from rainfall, and warm temperatures during the harvest period, and mechanical abuse during harvesting and handling operations. Production of high quality soybean seed requires timely harvest followed by aeration or drying, or both, as necessary to reduce seed moisture content to 13 percent or less in temperate areas, and 12 percent or less in subtropical and tropical areas, and careful combining and handling to minimize mechanical damage.

In subtropical and tropical areas soybean seed should be stored in an air-conditioned storehouse with conditions of 20° to 22°C or less and 60 percent relative humidity or less, to maintain quality from harvest to planting.

Germination percentage is not always a reliable index of the stand and crop producing potential of soybean seed. Seed lots of good germination but low in vigor can and do perform poorly in the field even under rather favorable conditions. Therefore, use of vigor tests to supplement information provided by the germination test is recommended.

REFERENCES

1. Abu-Shakra, S.S., and T.M. Ching. 1967. Mitochondrial activity in germinating new and old soybean seed. Crop Sci. 7:115-118.

2. Andrews, C.H. 1966. Some aspects of pod and seed development in Lee soybeans. Ph.D. dissertation. Mississippi State University.

3. Andrews, C.H. 1970. Storage of soybean seed studied. Miss. Farm Res. 33:3, 5.

4. Andrews, C.H. 1973. Influence of physiological quality of seed on performance of crops. Agron. Abstr. p. 49. American Society of Agronomy, Madison, Wis.

5. Andrews, C.H., and C.E. Vaughan. 1972-1973. Unpublished data. Seed Technology Laboratory, Mississippi State University.

6. Anonymous. 1973. Soybean drying can ease the next bad harvest. Soybean Dig. 34 (Aug):18-20.

7. Anthow, K.L., and R.M. Caldwell. 1956. The influence of seed treatment and planting rate on the emergence and yield of soybeans. Phytopathology 46:91-95.

8. Association of Official Seed Analysts. 1970. Rules for testing seed. Proc. Assoc. Off. Seed Anal. 60:1-116.

9. Association of Seed Certifying Agencies. 1971. AOSCA certification handbook. AOSCA Publication No. 23.

10. Barber, G., C. Hendrix, and C.R. Weber. 1972. Our experiences with soybean fungicides. In Proc. 2nd soybean conference. American Seed Trade Association, Washington, D. C.

11. Barger, E.L., and C.R. Weber. 1949. Harvest losses in soybeans. Iowa Farm Sci. 3:8-10.

12. Barnes, H.H. 1968. Soybean storage pays. The Furrow (John Deere), Sept.-Oct., pp. 22-23.

13. Byrd, H.W. 1970. Effect of deterioration in soybean (*Glycine max*) seed on storability and field performance. Ph.D. dissertation. Mississippi State University.

14. Byrd, H.W., and J.C. Delouche. 1971. Deterioration of soybean seed in storage. Proc. Assoc. Off. Seed Anal. 61:41-57.

15. Christensen, C.M., and H.H. Kaufman. 1969. Grain storage--the role of fungi in quality loss. University of Minnesota Press, Minneapolis.

16. Christiansen, M.N., and R.O. Thomas. 1971. Seed hydration--chilling effects on germination and subsequent growth and fruiting of cotton. Crop Sci. 11:454-456.

17. Delouche, J.C. 1968. Physiology of seed storage. Pages 83-90 in Proc. 23rd corn and sorghum res. conf. American Seed Trade Assn., Washington, D.C.

18. Delouche, J.C. 1968. Precepts for storage. Pages 85-119 in Proc. 1968 short course for seedsmen. Mississippi State University.

19. Delouche, J.C. 1972. Harvesting, handling and storage of soybean seed. Pages 17-22 in Proc. 1972 short course for seedsmen, Vol. 15. Mississippi State University.

20. Delouche, J.C., and C.C. Baskin. 1971. Unpublished data. Seed Technology Laboratory, Mississippi State University.

21. Delouche, J.C., and C.C. Baskin. 1973. Accelerated aging tests for predicting the relative storability of seed lots. Seed Sci. and Tech. 1:427-452.

22. Delouche, J.C., R.L. Agrawal, and B. Rajanna. 1970. Unpublished data. Seed Technology Laboratory, Mississippi State University.

23. Delouche, J.C., and W.P. Caldwell. 1960. Seed vigor and vigor tests. Proc. Assoc. Off. Seed Anal. 50:124-129.

24. Delouche, J.C., R.K. Matthes, G.M. Dougherty, and A.H. Boyd. 1973. Storage of seed in sub-tropical and tropical regions. Seed Sci. and Tech. 1:663-692.

25. Delouche, J.C., T.W. Still, M. Raspet, and M. Lienhard. 1962. The tetrazolium test for seed viability. Miss. Agr. Exp. Sta. Tech. Bull. 51.

26. Everson, L.E. 1972. The use of test information in quality control and sales. Pages 87-92 in Proc. 1972 short course for seedsmen, Vol. 15. Mississippi State University.

27. Fehr, W.R., J.S. Burris, and D.F. Gilman. 1973. Soybean emergence under field conditions. Agron. J. 65:740-742.

28. Grabe, D.F. 1965. Storage of soybeans for seed. Soybean Dig. 26(1):14-16.

29. Grabe, D.F. 1972. Laboratory germination of soybeans versus field performance. In Proc. 2nd soybean conference. American Seed Trade Association. Washington, D. C.

30. Grabe, D.F. 1972. Components of seed vigor and their effects on plant growth and yield. Agron. Abstr. (ASA) p. 57.

31. Grabe, D.V., ed. 1970. Tetrazolium testing handbook. Contribution No. 29. Handbook on seed testing. Association of Official Seed Analysts.

32. Green, D.C., L.E. Cavanah, and E.L. Pinnell. 1966. Effects of seed moisture content, field weathering and combine cylinder speed on soybean seed quality. Crop Sci. 6:7-10.

33. Green D.E., V.D. Luedders, and B.J. Moraghan. 1971. Heritability and advance from selection for six soybean seed quality characters. Crop Sci. 11:531-533.

34. Green, D.E., and E.L. Pinnell. 1968. Inheritance of soybean seed quality. I. Heritability of laboratory germination and field emergence. Crop Sci. 8:5-11.

35. Green, D.E., and E.L. Pinnell. 1968. Inheritance of soybean seed quality. II. Heritability of visual ratings of soybean seed quality. Crop Sci. 8:11-15.

36. Harrington, J.F. 1972. Seed storage and longevity. Pages 145-246 in T.T. Kozlowski, ed. Seed biology. Vol. 3. Academic Press, Inc., New York.

37. Harris, H.B., M.B. Parker, and B.J. Johnson. 1965. Influence of molybdenum content of soybean seed and other factors associated with seed source on progeny response to applied molybdenum. Agron. J. 57:397-399.

38. Heydecker. W. 1972. Vigour. Pages 209-252 in E.H. Roberts, ed. Viability of seeds. Syracuse University Press, Syracuse, N.Y.

39. Holman, L.E., and D.G. Carter. 1952. Soybean storage in farm-type bins. Illinois Agr. Exp. Sta. Bull. 553.

40. Isely, D. 1957. Vigor tests. Proc. Assoc. Off. Seed Anal. 47:176-182.

41. Lamp, B.J., K.A. Harkness, W.H. Johnson, and P.E. Smith. 1962. Soybean harvesting--approaches to improved harvesting efficiencies. Ohio Agr. Exp. Sta. Res. Bull. 899.

42. Lanyon, L. 1970. Have you had problems with soybean emergence? Crops and Soils 23(1):13-14.

43. McNeal, X. 1966. Conditioning and storage of soybean. Ark. Agr. Exp. Sta. Bull. 714.

44. Miller, D.L. 1970. Mechanical kernel damage and field losses of soybeans during harvesting. M.S. thesis. Mississippi State University.

45. Mondragon, R.L. 1972. Field deterioration of soybean seed exposed to different environments. M.S. thesis. Mississippi State University.

46. Monti, W. 1972. How to minimize damage in handling, processing and shipping soybean seed. In Proc. 2nd soybean conference. American Seed Trade Association, Washington, D. C.

47. Moore, R.P. 1962. Tetrazolium as a universally accepted quality test of viable seed. Proc. Int. Seed Test. Assoc. 27(3):795-805.

48. Moore, R.P. 1966. Tetrazolium--best method for evaluating seed life--advises consideration. Seedsmen's Dig. 17(11):38-40.

49. Park, J.K., and B.K. Webb. 1959. Soybean harvesting losses in South Carolina. S. C. Agr. Exp. Sta. Circ. 123.

50. Perry, D.A. 1972. Seed vigor and field establishment. Hort. Abstr. 42:334-342.

51. Pollock, B.M., and E.R. Roos. 1972. Seed and seedling vigor. Pages 313-387 in T.T. Kozlowski, ed. Seed biology. Vol. 1. Academic Press, Inc., New York.

52. Popinigis, F. 1972. Immediate effects of mechanical injury on soybean seed. M.S. thesis. Mississippi State University.

53. Roberts, E.H. 1972. Loss of viability and crop yields. Pages 307-320 in E.H. Roberts, ed. Viability of seeds. Syracuse University Press, Syracuse, N. Y.

54. Toole, E.H., and V.K. Toole. 1946. Relation of temperature and seed moisture to viability of stored soybean seed. U.S. Dept. Agr. Cir. 753.

55. Tyler, D. 1972. Seed conveying--problems and solutions. Pages 47-69 in Proc. 1972 Short Course for Seedsmen, Vol. 15. Mississippi State University.

56. Vaughan, C.E., B.R. Gregg, and J.C. Delouche, eds. 1968. Seed processing and handling. Handbook No. 1. Mississippi State University.

57. Walters, H.J., and C.E. Caviness. 1973. Breeding for improved seed quality. Arkansas Farm Res. 23(5):5.

58. Woodstock, L.W. 1969. Seedling growth as a measure of seed vigor. Proc. Int. Seed Test. Assoc. 34:273-280.

59. Woodstock, L.W. 1973. Physiological and biochemical test for seed vigor. Seed Sci. and Tech. 1:127-157.

Economic Evaluation of Simultaneous Development of Production and Processing of Soybeans in India

M. von Oppen

Over the past ten years several countries have experienced large increases in soybean production (Table 1). Some of these countries, such as Argentina, Paraguay, Romania, and India, have started their soybean production from virtually zero levels and it is interesting to take a look at their rates of expansion of acreage (Fig. 1).

The countries included in this comparison were selected for their high increases in acreage under soybeans during the last 10 years. Experience from these countries shows that the higher the absolute levels of production the more rapid are the increases in area under soybeans until an upper limit is approached. During the early stages, soybean development is restricted by a lack of processing facilities, and processing facilities generally are slow to come up until certain minimum quantities of soybeans are available in sufficient densities for processing in large-scale industrial operations. (For instance, when Paraguay reached the point of take-off in 1970, it had a production density of 20,000 ha over its total land area of about 406,000 km^2, i.e., 0.05 t/km^2 of total land area. Romania in 1970 achieved its production increase at a production density of about 0.3 t/km^2.)

India is the last country in this group to join the "soybean race" and so far its soybean expansion has been somewhat slower than that of most of the countries shown. On the other hand, Fig. 1 shows clearly that India pursues an ambitious target of soybean development: 430,000 ha in 1979. The question one might ask is: Will India be able to achieve these targets?

Considering India's and the other countries' rates of expansion of soybean acreages during recent years, it would seem that the future expansion in India is likely to remain about 50 percent behind the targets envisaged--i.e., perhaps 200,000 ha by 1979 would seem a plausible figure, assuming market conditions similar to those prevailing during 1970 to 1972, for which we have data for the other countries.

In fact, India does have a particularly complicated problem to solve. Soybeans will have to find a market within India, because Indian wholesale price levels for food products are generally above world market prices, and the Government of India so far does not financially support the export of soy meal. Rather, it considers soy meal a human food to be consumed domestically, although it does not support this idea very actively. Consequently, while she is expanding the area under soybeans, India must simultaneously build up a good industry to process and market soy meal and oil for human consumption if she wishes the industry to grow at anywhere near target rates.

In order to evaluate the situation in India I want to present some observations. These are based on information on agricultural production, marketing and processing, and the role of the Government of India with respect to soybean development during the past 4 or 5 years. In this way we can obtain clues as to some of the prevailing trends and approaches. From these we can then draw conclusions about the likely direction and speed of future development of soybeans in India.

Agricultural Production of Soybeans

There is evidence from data gathered over the past 4 years on the economics of production and processing of soybeans indicating that its competitive strength over other crops gradually increases.

Farm survey data on costs of production of soybeans and competing crops in Madhya Pradesh are available for 4 years, from 1970/71 to 1973/74 (5, 6, 7). Analysis of the data has shown that the net returns to farmers from soybeans were generally higher than those from maize, jowar, and groundnut, so that the "majority of farmers included in this study consider soybeans to be a superior crop to all the competing Kharif season crops" (6). In

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Table 1. Production and export-import of soybeans and soy products in selected countries.

Country[a]	Year	Soybean Production (1,000 mt)	Net exports (+) / Net imports (-) Soybeans (1,000 mt)	Soy oil (1,000 mt)	Soy meal (1,000 mt)
Brazil	1961-1965	353	n.a.	n.a.	n.a.
	1970	1,509	+ 290	- 2	+ 525
	1971	1,977	+ 200	- 4	+ 901
	1972	3,500	+ 1,039	+ 48	+ 1,432
Argentina	1961-1965	12	n.a.	n.a.	n.a.
	1970	27	--	--	--
	1971	59	--	--	--
	1972	78	--	--	--
Paraguay	1961-1965	8	n.a.	n.a.	n.a.
	1970	30	+ 1	+ 1	+ 28
	1971	74	+ 12	+ 1	+ 30
	1972	128	+ 42	+ 1	+ 28
Mexico	1961-1965	65	n.a.	n.a.	n.a.
	1970	280	- 90	- 3	--
	1971	250	- 50	- 1	--
	1972	360	- 11	- 1	--
Romania	1961-1965	3	n.a.	n.a.	n.a.
	1970	91	+ 10	--	--
	1971	165	+ 20	--	--
	1972	170	+ 20	--	--
Thailand	1961-1965	27	n.a.	n.a.	n.a.
	1970	70	+ 6	--	+ 4
	1971	74	+ 6	--	+ 1
	1972	70	+ 7	--	+ 1
India	1961-1965	--[b]	--	--	--
	1970	8	--	79	--
	1971	18	--	177	--
	1972	24	--	80	--
	1973	32	--	--	--

a/ Countries in which area under soybeans increased by at least about 200 percent or more between 1961-1965 and 1972.

b/ Cream-colored varieties only. Production and local consumption of traditional black varieties, mainly in the hilly areas of North India, is about 6,000 mt per year.

Sources: India: Rathod and Motiramani (8) and the author's estimates of yield of 7.5 t/ha. Other countries: FAO (2, 3).

order to compare the basic food values of the different crops irrespective of the market values, agricultural production costs of soybeans and competing crops per unit of protein and per unit energy were computed from the farm survey data. A comparison on this basis enables us to evaluate the relative agricultural costs at which food from these crops is produced in the farmers' fields over time.

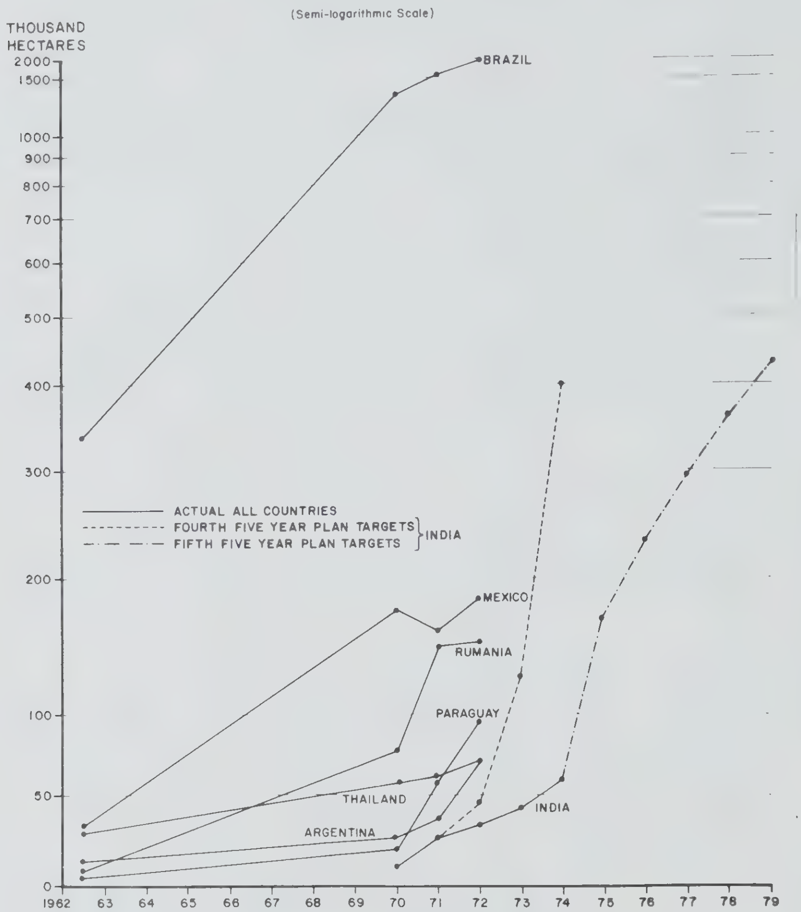

Fig. 1. Actual expansion of the area under soybeans in selected countries and targets of India (semilogarithmic scale).

As shown in Fig. 2, from the outset of the observations in India in 1970 soybeans have always been the most economic protein crop in terms of agricultural production costs per kilogram of protein. This is due to the high protein content of soybeans and therefore hardly surprising. Also according to the data available, during the past 4 years agricultural production cost of protein from soybeans has remained about constant, while for the three major competing crops protein costs have considerably increased.

If we compare the agricultural production costs of energy from soybeans and competing crops (Fig. 3) we note that at the outset of the farm surveys, calorie production from soybeans was more expensive than that from any of the other crops. But, over the subsequent 3 years, the costs of producing energy from competing crops increased to the extent that by 1973/74 soybeans were the cheapest source also of calories for human consumption from among these crops. It is stressed that this includes observations on only three competing kharif crops, namely, maize, jowar, and groundnuts. But these are generally considered to be the strongest competitors for soybeans in Madhya Pradesh.

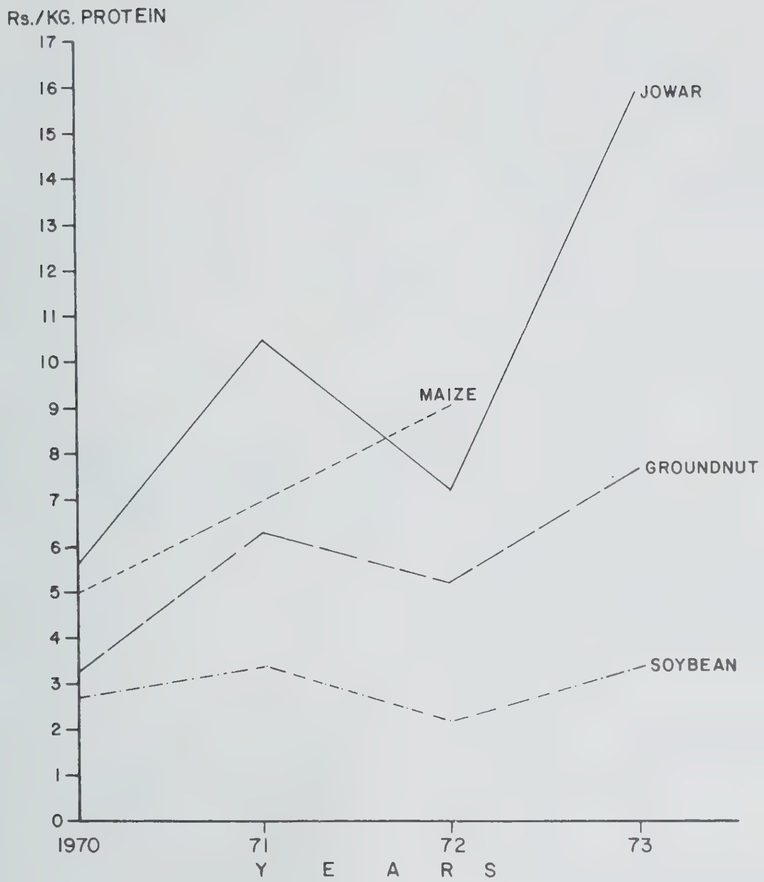

Fig. 2. Agricultural production costs per kilogram of protein from different crops in Madhya Pradesh, India.

These data were collected from farmers who were growing one or the other of the competing crops together with soybeans. Therefore, the skills they have in growing soybeans are also applied to the other crops. Even though only a small fraction of the farmers surveyed were included during all four years of observations, for the aggregate of all farmers observed, a considerable learning process has taken place that has led to a consistent relative decrease in costs and/or simultaneous increase in yields as experience in growing soybeans was accumulated and spread. (When we are talking about Madhya Pradesh and the spread of experience it must be borne in mind that Madhya Pradesh alone covers an area of about 44 million ha and soybeans are mainly grown in the western half, which has about the same size as the total area of Romania with 24 million ha.)

This is explained by the fact that in comparison to other crops soybean production requires a relatively sophisticated technology. In order to statistically evaluate the factors affecting yields of soybeans in India, farm survey data consisting of 400 observations in eight different districts of Madhya Pradesh for two years, 1970/71 and 1970/72, were subjected to multiple regression analysis. (These data collected, tabulated and also analyzed using cross tabulation and ranking techniques by Kashive and Williams (7). The author is grateful for being allowed to work on the data. Restrictions in time and in computer capacity made it impossible at this point to explore the given data statistically to the extent that this excellent information deserves. However, it is planned to pursue this work in the future.) These data contained detailed information on inputs such as seed, fertilizer, inoculum, insecticides, and bullock and human labor for different activities, as well as records of date and depth of planting and observations about exogenous factors such as bird damage, dry spells, and heavy rains after emergence of the crop. Plant population and yields were also recorded. Further, farmers' experience in growing soybeans is reported in terms of number of years.

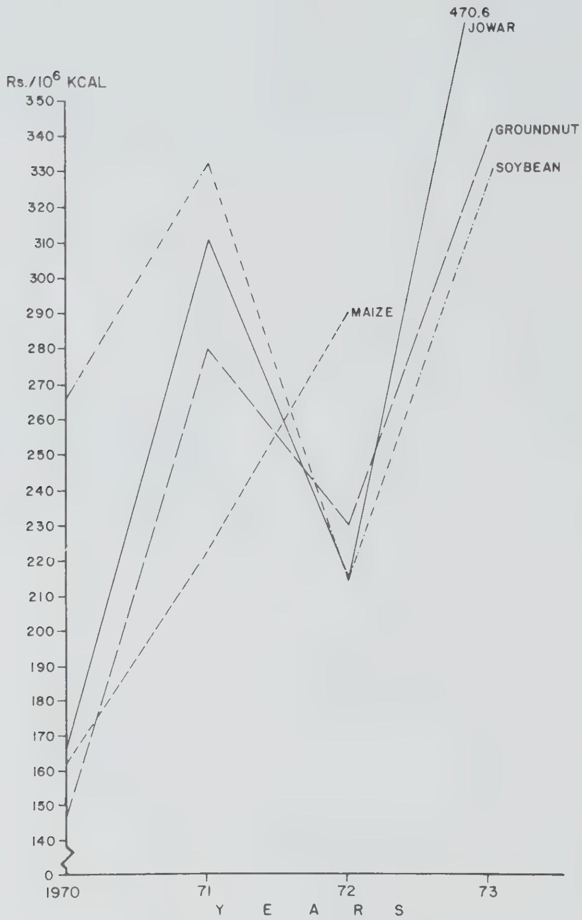

Fig. 3. Agricultural production costs per 10^6 kcal from different crops in Madhya Pradesh, India.

Since the number of variables that could be included in one equation was restricted by the capacity of the computer, the variables were grouped into two sets. On the basis of a priori information that plant population and yield are highly correlated (7, p.95), two regressions were run--the *first* regression to evaluate factors that determine the plant population, the *second* regression to evaluate factors (including plant population) that determine yield.

The following two equations were fitted, yielding regression coefficients (t - values in brackets) with significance levels indicated as follows (*** = significant at .9995 level; ** = significant at .90 level; * = significant at .75 level):

$$(1)\quad POP = \underset{}{123.8} + \underset{(1.16)^{*}}{12.07\ EXP} + \underset{(1.502)^{**}}{5.131\ DPL}$$

$$- \underset{(1.521)^{**}}{.0642\ (DPL)^2} + \underset{(1.64)^{**}}{9.713\ SDR} - \underset{(1.61)^{**}}{.1415\ (SDR)^2}$$

$$- \underset{(5.57)^{***}}{3.399\ DTE} + \underset{(5.61)^{***}}{61.28\ HRN} - \underset{(.311)}{3.447\ DRY}$$

$$- \underset{(8.06)^{***}}{79.41\ BRD} - \underset{(.384)}{.1033\ LPR}$$

$$R^2 = .39$$

$$
\begin{aligned}
(2)\quad \log YLD = & -.888 + \underset{(.010)}{.00023} \log NS + \underset{(.965)^{*}}{.0199} \log NR - \underset{(1.637)^{**}}{.0342} \log PKS \\
& -\underset{(.441)}{.009} \log PKR - \underset{(.186)}{.0393}\, INO + \underset{(3.22)^{***}}{.0379} \log SPR \\
& -\underset{(1.60)^{**}}{.077} \log LFS + \underset{(3.27)^{***}}{.040} \log LII + \underset{(1.36)^{*}}{.029} \log LSW + \underset{(14.71)^{***}}{.396} \log LHT \\
& + \underset{(10.45)^{***}}{.278} \log LTW + \underset{(.056)}{.0007} \log POP
\end{aligned}
$$

$$R^2 = .76$$

In these equations, the variables are:

POP = Plant population in 1,000 plants per ha.
EXP = Number of years grower grew soybeans before.
DPL = Depth of planting in millimeters.
SDR = Seed rate in kilograms per acre.
DTE = Date of planting in number of days before (-) or after (+) June 26.
HRN = Incidence of heavy rains at the time of emergence (Yes = 1 or No = 0).
DRY = Incidence of hot and dry weather at the time of emergence (Yes = 1 or No = 0).
BRD = Bird and insect damage after emergence (none = 0, medium = 1, heavy = 2).
LPR = Labor input in preparing the land in man hours per acre.
YLD = Yield in quintals per acre.
NS = Nitrogen on soybeans in kilograms of the element per acre.
NR = Nitrogen on preceding rabi crop in kilograms of the element per acre.
PKS = Phosphorus and potassium on soybeans in kilograms of the element per acre.
PKR = Phosphorus and potassium on preceding rabi crop in kilograms of the element per acre.
INO = Inoculum (yes = 1 or No = 0).
SPR = Insect spray expenditure in rupees per acre.
LFS = Man and woman labor hours per acre in fertilizing, seeding.
LII = " " " " " " " " interculture, irrigation.
LSW = " " " " " " " " spraying, weeding.
LHT = " " " " " " " " harvesting, transport.
LTW = " " " " " " " " threshing, winnowing.

It is agreed that this approach has not given best estimates in the pure statistical sense, as the information collected in fact involves a system of simultaneous equations. For instance one could postulate the following:

i) POP = f(EXP, DPL, SDR, DTE, HRN, DRY, BRD, LPR, NR, PKR, LSW, LII)
ii) YLD = g($\hat{POP}$, EXP, NS, NR, PKS, PKR, INO, SPR, LFS, LII, LSW, LHT, LTW)
iii) POP = h(EXP, DPL, SDR, DTE, HRN, DRY, BRD, LPR, NP, PKR, LSW, LII, NS, PKS, INO, SPR, LFS, LHT, LTW)

where $\hat{POP}$ is estimated from equation (iii)

The information therefore should be treated as a system of simultaneous equations. Also no differentiation among years and between regions was made and therefore no comparative location specific information could be derived. But for the time being we may use our estimates as first approximations.

Plant population is positively associated with heavy rains (a fact which runs contrary to the generally held opinion that heavy rains damage the crop; apparently if the damaging effect of rains is there, it is more than offset by positive effects on plant growth--at least this is so for the aggregate of all observations over two years in eight different locations, three of which are included in both years). Bird and insect damage naturally have a significant negative effect on plant population. The date of planting also is of significance for plant population: generally, the earlier the planting date before June 26, the better the plant stand. Seed rate and depth of planting each influence plant population in a similar fashion: as expressed by one linear and one quadratic term of each variable there is one optimum value for each variable above and below which the plant population decreases. (These values are found by taking the first partial derivatives with respect to the variables and setting them equal to zero, providing that the second derivative is negative.) According to our estimates the optimum depth of planting was 40 mm

and the optimum seed rate was 34 kg/acre, for a maximum plant population. Even though less significant, the experience of the grower in growing soybeans in earlier years has a positive effect upon plant population. The incidence of a dry spell after emergence and the amount of labor input for land preparation both influence plant stands only at a level of 60 percent significance.

In equation (2) it is found that nitrogen fertilizer does not have a significant effect upon soybean yields and that phosphorus and potassium applied on soybeans are negatively correlated with yields. Accordingly also labor input for fertilizing (and sowing) is at a significant level inversely associated with yield. All other labor inputs and also expenditures on insect spraying are related to yield. The insignificant coefficient for inoculum must be attributed to the fact that "inoculum was generally used by soybean growers in both years" (7, p.13) and therefore the variable was lacking variation to show the impact of inoculum. The insignificant coefficient for the plant population possibly indicates a misspecification of the variable or of the system.

These data provide some information on the potential for improving soybean yields and/or reducing agricultural production costs by accumulating experience with this crop.

The results indicate the extent to which farmers' activities do or do not contribute to yields. We have arrived at these findings by statistically analyzing the data collected from some 400 farmers. However, on an intuitive basis every individual farmer over time also discovers similar relationships, particularly those valid for his own conditions. This learning process undoubtedly contributed to the 40 percent decline in production costs of protein and calories over 4 years. On these grounds relatively high pay-offs, are to be expected from extension and demonstration efforts, which aim not only at expansion of acreage but also at the improvement of soybean yields.

MARKETING AND PROCESSING OF SOYBEANS AND SOY PRODUCTS

During the first years of soybean development in India, the majority of production was probably marketed and sold under some kind of written or oral contractual arrangement (9). This is a very reasonable approach for the early stages of soybean marketing, as it reduces several types of risks for both buyers and sellers. However, in the long run a cash grain crop like soybeans is marketed more efficiently in the open market (12, p.38). In fact, since 1972 and more so in 1973, soybeans have appeared in several market places in Madhya Pradesh where prices of up to Rs 150/qtl (Indore, December 1972) and Rs 240/qtl (Ujjain, March 1974) were reported (Table 2). Despite the increase in soybean production from 1972 to 1973 of 34 percent the average November-December price during the same period rose by 21 percent, which is quite in line with the price increases of 25 percent of groundnuts and maize over that period. In regard to jowar, in Ujjain extraordinary shortages of this crop in that area are responsible for the steeper price rise; in other markets, e.g., Akola and surrounding areas, prices for jowar also increased by 21 percent.

These stable prices for soybeans, in comparison to other crops, are indicating an increasing demand. This growing demand for soybeans cannot only be attributed to a general shortage of vegetable oil in India, because soybeans have less than half the oil content of groundnuts, and there is no preference for soy oil over groundnut oil. The rise in soybean prices is due to an increasing awareness of the qualities of soybean protein and a consequent increase in demand for this product. Soybeans are processed into so-called Dal (split pulses) (the official government support price is 100 rupees per quintal) and sold in a mixture with dal of customary pulses. The extent to which this "fortification by adulteration" is practiced is not known. The pharmaceutical industry is using soy meal or soybeans on a large scale for the production of antibiotics, and some industrial soy meal is also used and even exported for feed purposes. To a lesser extent (but at an increasing rate) soybean processors are producing soy meal of edible quality, which is processed into food products (Table 3).

The exact number of soybean processing plants in India is unknown, but informed sources estimate that at present about twelve mills are operating, five of which are of the solvent extraction type with an average capacity of about 50 mt/day each. Five are screw press-type expellers with an average capacity of about 2 mt/day each, and two are special types, one an extrusion cooker plant and another a soymilk plant, both still more or less at the experimental stage although not far from entering the commercial market. (Personal information from K.L. Rathod and from the Directorate of Oilseeds Development, Government of India, Hyderabad.)

Table 2. Weekly prices for soybeans and competing crops in selected primary markets of North India in November and December of 1972 and 1973 in rupees per quintal.

Year	Month	Week	Soybeans	Groundnuts (in shell)	Jowar (yellow)	Maize (white)
			Indore	*Rajkot*	*Ujjain*	*Baraich*
1972	Nov.	1st	--	175	--	63
		2nd	120	180	--	65
		3rd	135	175	--	64
		4th	130	180	64	65
	Dec.	1st	147	190	69	65
		2nd	147	180	69	66
		3rd	140	175	67	66
		4th	150	180	67	72
Two months' av			138.40 (100)	179.40 (100)	66.80 (100)	65.80 (100)
			Indore	*Rajkot*	*Ujjain*	*Baraich*
1973	Nov.	1st	135	219	126	75
		2nd	150	219	127	75
		3rd	145	235	131	80
		4th	158	214	115	80
	Dec.	1st	161	214	112	85
		2nd	183	225	113	90
		3rd	210	247	--	90
		4th	198	--	107	--
Two months' av			167.50 (121)	225.30 (125)	118.70 (178)	82.10 (125)

Sources: Soybean Marketing Information, No.13, May-August 1974, and Bulletin of Agricultural Prices, Vols. 22 (1972) and 23 (1973), No. 45 to 52.

Table 3. Recorded soybean processing capacity in India.

Type of processing plant	Recorded as operating in 1974			Recorded as operating in 1975		
	No. of plants	Capacity (mt/day) Total	Capacity (mt/day) Average	No. of plants	Capacity (mt/day) Total	Capacity (mt/day) Average
			Producing edible quality soy meal			
Screw press expellers	4	7	1.8	5	8	1.6
Solvent extraction plants	2	120	60	4	240	60
Extrusion cookers plant	1	*/	*/	1	*/	*/
Soymilk extraction plant	1	*/	*/	1	*/	*/
			Industrial quality soymeal			
Screw press expellers	1	4	4	1	4	4
Solvent extraction plants	3	145	48	5	335	67
Total	12	276		15	587	

*/ Experimental stage.

Sources: Rathod and Motiramani (8, 9) and Directorate of Oilseeds Development, Government of India.

At present annual production of about 45,000 t of soybeans in India the total capacity of these plants of 276 t/day, or 83,000 mt/300 days in a year, can be utilized for soybeans to only about 50 percent capacity. However, most of the solvent extraction plants that are reported to process soybeans are in fact mills that were originally set up and still continue to process groundnuts. Not all of these plants are adapted to produce edible soy meal. Only if these mills are equipped with an additional toasting device and if they observe certain hygienic standards can they produce a soy meal of edible quality.

The estimated average costs of processing one ton of soybeans by different methods are ranging between 174 to 640 rupees (Table 4). The estimate of Rs 174/t refers to a solvent extraction plant of 10 t/day capacity, if used at full capacity. A plant of 100 t/day capacity would process at costs of about Rs 75/ton (Fig. 4). These economies of scale in solvent extraction plants promise some additional incentives to the soybean industry as larger-scale plants find sufficient quantities of soybeans for processing at full capacity. However, when adding industrial processing and transportation cost plus agricultural production costs (Table 5) it is found that for soybeans the former contribute only 15 to 20 percent while the latter account for 85 to 90 percent of the sum of these costs.

Table 4. Average costs of processing soybeans by different methods.

Method of processing	Extrusion cooking[a/] (capacity 20 t/day)	Solvent extraction[b/] (capacity 10 t/day)	Screw press expelling[b/] (capacity 1 t/day)	Milk extraction[c/] (10,000 liters/day = 1 t/day)	Dal preparation[d/] (1 t/day)
	Rs/t	Rs/t	Rs/t	Rs/100 liters	Rs/t
Variable costs	90	43	100	38.78	490
Fixed costs for capital	170	131	89	7.67	150
Total average costs	260	174	189	46.45	640

Sources: a/ Rathod and Williams (10).
b/ Williams and Rathod (13).
c/ Communication of Director of Research Services, J. Nehru Krishi Vishwa Vidyalaya, Jabalpur, to L. Sabha question No.2112 on value of soymilk, August 1974.
d/ Spata et al. (11).

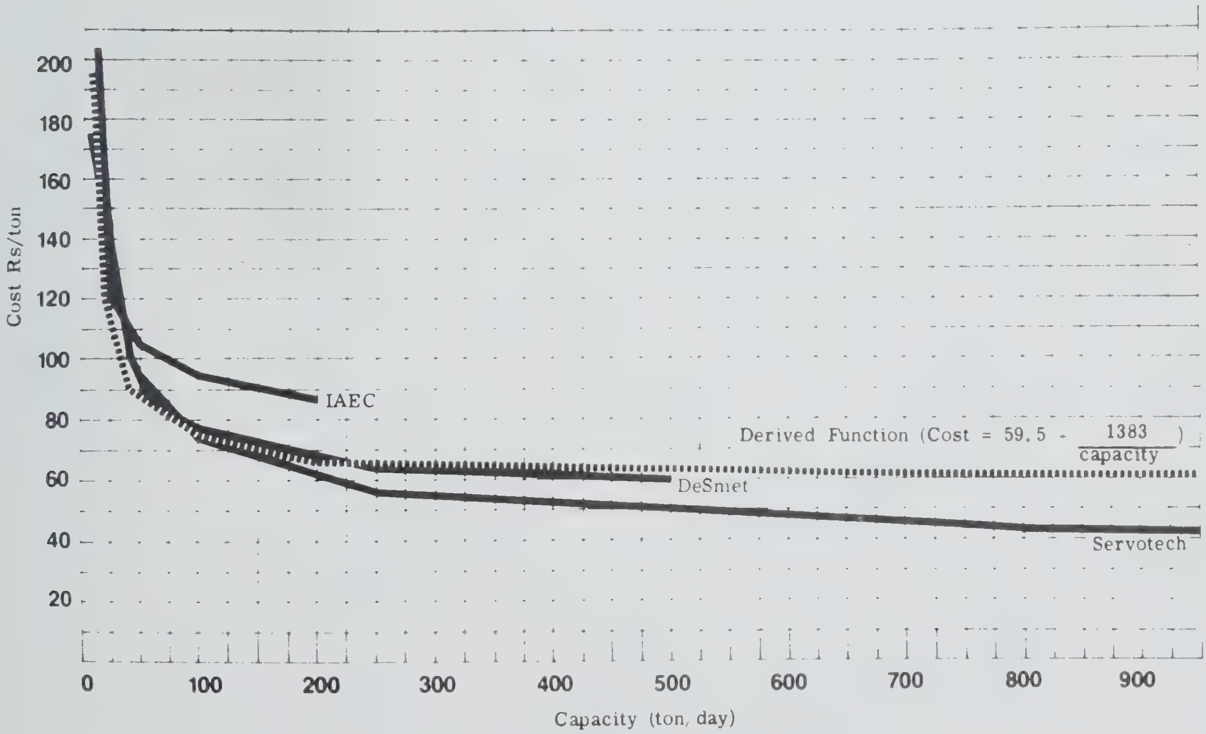

Fig. 4. Average costs of processing soybeans in India (estimates by three engineering firms and derived average cost function).

Table 5. Production costs of protein (Rs/50 g) and energy (Rs/2,500 kcal.)

	Soybeans		Groundnuts		Jowar		Maize	
	Protein	Energy	Protein	Energy	Protein	Energy	Protein	Energy
Agricultural production costs[a/]	.14	.72	.30	.66	.51	.76	.32	.52
Industrial Processing plus transportation costs[b/]	.03 (.02)	.15 (.09)	.03	.06	--	--	--	--
Total costs	.17 (.16)	.87 (.81)	.33	.72	.51	.76	.32	.52

a/ Average costs 1970-1973.
b/ Estimates 1971-1972--for soybeans Rs 250/t; figures in parentheses refer to processing costs of Rs 150/t.
--for groundnuts Rs 125/t.

Source: Computed from data in Fig. 2, 3 and Table 4.

Consequently, if the observed trend of lowered production costs for protein and energy from soybeans relative to competing crops of about 10 percent per year continues for several more years, then this effect will, for the near future, contribute most of the increasing incentive in expanding the area under soybeans. Nevertheless, it must be stressed that in the long run the cost reducing effects of economies of scale in soybean processing and marketing will not be negligible, if the plants are placed at optimum locations and laid out so that provision is made for later expansions of the facilities within the plant.

The optimal location of a soybean processing plant is determined by the regional densities of soybean production, by the location of consumption centers for soy meal (e.g., food industry) and soy oil (vanaspati industry), by costs of processing (economies of scale), and costs of assembling soybeans, and by absolute and relative costs of long-distance transport of soybeans and soy products. Without going into all of the critical details of this field, some general principles should be spelled out:

1. Soybean cultivation will be developed predominantly in North Central India (Fig. 5), where soybeans are expected to find a place in cropping patterns as an intercrop (e.g., in cotton), or on kharif fallow or by competing successfully against some of the present kharif crops. This forecast is proving to be quite correct although until now cultivation has expanded faster in the northern part of the area indicated in Fig. 5 (i.e., in Madhya Pradesh and Uttar Pradesh) and to a lesser extent in the east, west, and south (Bihar, Gujarat, Maharashtra, and Andhra Pradesh). This is because against earlier estimates the varieties presently available are apparently not that well suited for interculture in cotton and for the southern latitudes. However, according to government sources, soybean production is being promoted also in Karnataka from 1974 onwards as varieties have been found that are suitable for this area.

2. It is more economical to process soybeans in the vicinity of the areas where they are produced. The Indian Freight Rates for Rail Shipments classify soybeans such that the costs of transporting one metric ton of soybeans over 500 km are Rs 47.80. In comparison to these costs the shipping over the same distance of 1.7 qunitals of oil costs Rs 7.84 and of 80 quintals of soy cake costs Rs 15.20; that amounts to a total of Rs 23.04. In other words, about 25 rupees per ton, or over 50 percent of transportation costs, are saved when shipping the soy products rather than transporting soybeans.

3. The costs of soybean assembly increase as processing plants increase in size, because the hauling distances become larger. At the same time, due to economies of scale, processing costs decrease. The minimum of these costs indicates that the optimum plant size at present production densities is around 50 t/day and around 100 to 150 t/day when (by 1979?) the target of about 400,000 ha is reached (12, Table 11).

Out of the 12 plants with a combined 276 t/day capacity recorded as presently processing soybeans, only eight plants with a combined capacity of 150 t/day are located within our potential soybean production area, the others being located in places such as Aligarh, Calcutta, Bombay, and Poona. Unless these enterprises are able to realize considerable savings in costs exceeding Rs 25/t (e.g., by utilizing sunk capital in buildings or equipment etc.) their location at the present system of rail rates places them at a definite disadvantage in comparison to the other plants located within the areas of soybean production.

Role of Government

After extensive research initiated by the U.S. Agency for International Development (USAID) and supported by the Government of India had proved the potential for soybean production in India, soybeans were included in the oilseeds development program in kharif 1970, by a centrally sponsored scheme for demonstrations. In addition a centrally sponsored scheme for soybean development was sanctioned during 1971-1972 for the states of Madhya Pradesh, Maharashtra, Gujarat, and Uttar Pradesh. This scheme provided for: (a) a subsidy of 25 percent on cost of seed subject to a maximum of 60 rupees per quintal during the first year, (b) a 25 percent subsidy on insecticides, (c) a staff at field level to ensure timely supply of inputs and provide technical guidance to the farmers, and (d) training of extension staff in the cultivation techniques of soybeans.

Arrangements were also made for the import of inoculum to meet the needs of the 1971-1972 program and for domestic production of the 1972-1973 requirements. A support price of Rs 85/quintal was to be paid by the Food Corporation of India (FCI) which, even after a premium of Rs 15/Quintal was added, did not provide incentive for farmers to sell to FCI. An All-India Co-ordinated Research Project on Soybeans was initiated with a budget of 180,000 rupees for the period 1969-1974.

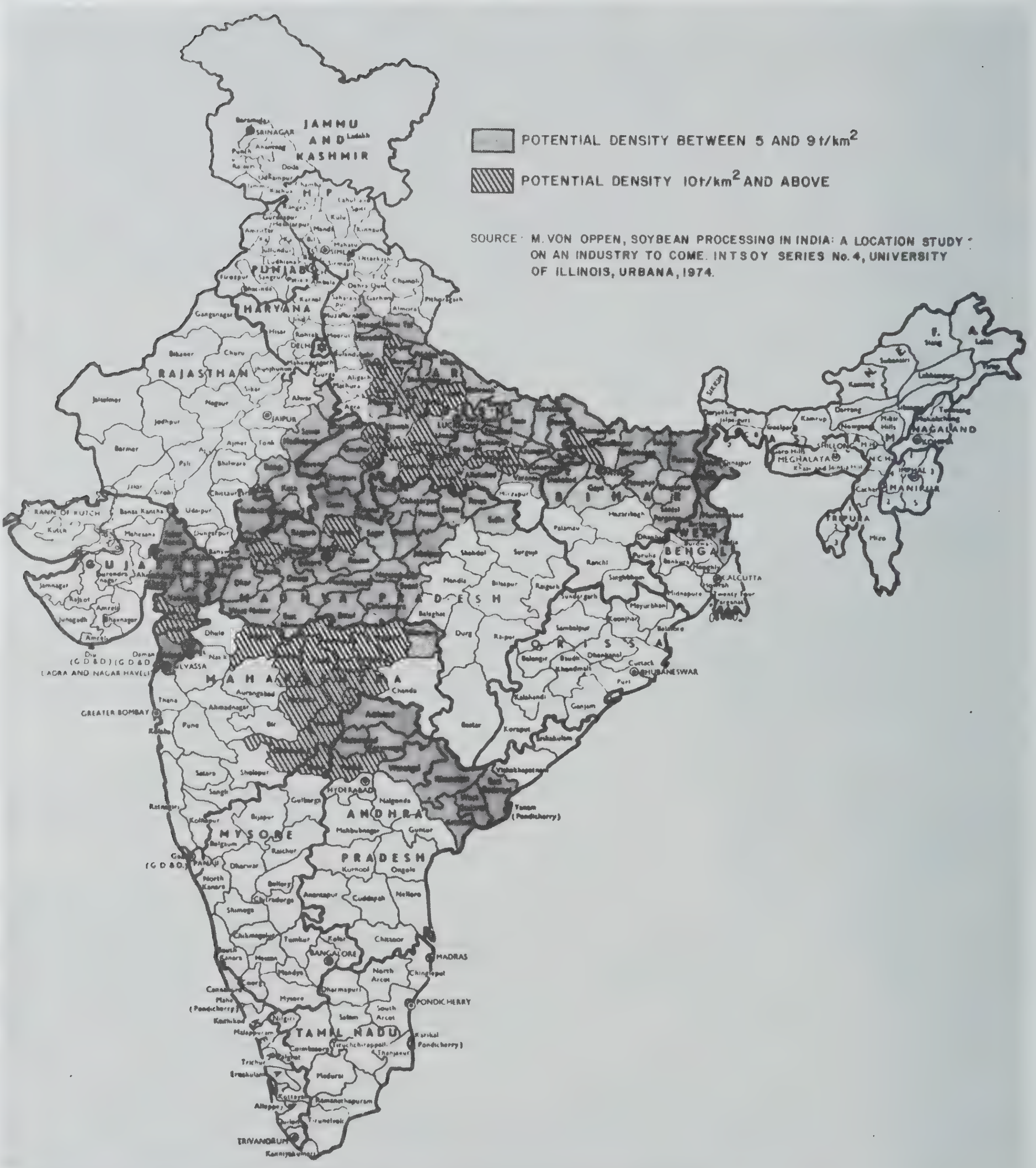

Fig. 5. Areas of potential soybean production in India.

Thus in the early phase of the soybean development program *soybean production* was emphasized. At the same time the development of marketing facilities was left relatively undisturbed, although in order to avoid a buildup of overcapacity in solvent extraction, the government has been somewhat reluctant in licensing new soybean processing facilities.

In the present Five-Year Plan period, (1974-1979) basically the same approach is continued. The production targets were adjusted by postponing the 400,000 ha level for 5 years from 1974 to 1979. About 25 million rupees were set aside for continuation of the centrally sponsored production development program. The budget for the All-India Co-ordinated Research Project on Soybeans was extended to 525,000 rupees. Apart from certain plans which have been discussed for almost five years, no real efforts have so far been initiated to establish a government-owned solvent extraction plant and protein food factory. (Latest versions of these plans are to locate a factory of 300 t/day in Faridabad near New Delhi.)

Rather than mislocate an oversized plant, it would probably be better to allow the soybean industry to develop on its own along free enterprise lines. On the other hand, it is true that the soy protein food industry has yet to develop considerably and that active government support could prove beneficial. A plant with a capacity of about 50 t/day located in central Madhya Pradesh (e.g., Bhopal or Indore) would probably serve the purpose, requiring about 15,000 tons of soybeans. Estimating that here, during the first year, in say 1975, perhaps about 10,000 tons of soybeans could be purchased locally (the area under soybeans in seven districts of western Madhya Pradesh in 1973 was 13,000 ha) an additional 5,000 tons of soybeans would be required to utilize the plant at full capacity. This quantity could almost certainly be imported on the basis of foreign food aid. If efficiently operated and promoted by an accompanying production development program, the plant could be running on domestically produced soybeans from 1976 onwards.

We ought to recognize, however, that the risk in setting up such a processing plant is constraining a public institution like Food Corporation of India probably more than it restricts private entrepreneurs; in fact, an administrator's fear of being held responsible for running a deficit during the first year or two in such a plant is not easily offset by his expectations of later gains.

CONCLUSION

The assessment of the past development of agricultural production and industrial processing and marketing of soybeans in India and of the position of the government suggests the following: Soybeans are gaining competitive strength in agricultural production, processing, and marketing as the area under soybeans expands. This is due to an aggregate accumulation of experience in technology and because of an increasing awareness among consumers of the potential uses of soybeans. Public support so far has been limited to promoting the development of agricultural production, while mostly private industries (especially the pharmaceutical and vanaspati industries) absorbed the quantities produced and processed them for final consumption. Even though in India during the past four years expansion of soybean acreage has been slow in comparison to other countries, there are reasons to expect that the development of soybean acreage will continuously accelerate. North Central India, where we primarily expect soybeans to be grown, covers a large area of roughly 800,000 square kilometers (about three times the size of Romania) and present production of soybeans is still spreading relatively thinly (.05 t/km[2/]) over that area.

A doubling of the present soybean area may still require about two or even three years. However, when a production density of .1 t/km[2/] is reached, it will be possible for a plant with a capacity of 50 mt/day to assemble its required 15,000 mt/yr from an area of about 150,000 km[2/], i.e., an area which, if circular, would have a radius of about 230 km. Even though the radius would be the maximum and the average distance would be about 150 km, these are fairly long but feasible distances to assemble soybeans by truck. It is at this level of about .1t/km[2/] that we can expect several sizeable plants to begin to process soybeans quite economically. In the soybean development program special efforts should be made to concentrate, rather than spread, further development and extension work, preferably in areas where there is already a processing plant.

According to the experience of other countries, once a production density of .1t/km[2/] is reached, preconditions for a rapid increase in the expansion of area under soybeans are given. Therefore, unless unforeseen problems develop (e.g., license restrictions, extreme weather hazards, diseases, and so on) we can conclude from the development of

production costs, supply, and demand over the past 4 to 5 years in India and from experience in other countries, that soybean development during the next two or three years is likely to remain behind the targets set in the fifth Five Year Plan. However, we may also conclude that during the following 2 to 3 years an increase will take place that exceeds that envisaged in the annual targets of that period. In summa, the target for 1979 of over 400,000 ha under soybeans appears quite likely to be reached.

REFERENCES

1. All-India Co-ordinated Research Project on Soybean. 1973. Proc. 6th workshop conference on soybean. University of Agricultural Sciences, Dharwar, and G.B. Pant University of Agriculture and Technology, Pantnagar, India.

2. Food and Agriculture Organization. 1972. Production year book. Vol. 26. Food and Agriculture Organization of the United Nations, Rome.

3. Food and Agriculture Organization. 1972. Trade year book. Vol. 26. Food and Agriculture Organization of the United Nations, Rome.

4. Government of India. 1973. Report of the study group for the formulation of 5th five-year plan proposals on oilseeds. Ministry of Agriculture, New Delhi.

5. Kashive, R.C. 1973. Economics of production of soybeans and competing kharif crops in Madhya Pradesh 1972-1973. Rpt. 6th workshop conference on soybean. University of Agricultural Sciences, Dharwar, India.

6. Kashive, R.C. 1974. Economics of production of soybeans and competing kharif crops in Madhya Pradesh 1973-1974. Rpt. 7th workshop conference on soybean. G.B. Pant University of Agriculture and Technology, Pantnagar, India.

7. Kashive, R.C., and S.W. Williams. 1972. Economics of soybean production in Madhya Pradesh. J. Nehru Krishi Vishwa Vidyalaya and University of Illinois/USAID, Jabalpur, India.

8. Rathod, K.L., and D.P. Motiramani. 1974. Status of the soybean industry in India. All-India co-ordinated research project. J. Nehru Krishi Vishwa Vidyalaya, Jabalpur, India.

9. Rathod, K.L., and D.P. Motiramani, eds. 1970. Soybean marketing information. (Issued quarterly) Directorate of Research Services, J. Nehru Krishi Vishwa Vidyalaya, Jabalpur, India.

10. Rathod, K.L., and S.W. Williams. 1972. Extrusion cooking--a breakthrough in soybean processing for human food. J. Nehru Krishi Vishwa Vidyalaya and University of Illinois/USAID, Jabalpur, India.

11. Spata, J.A., A.I. Nelson, and S. Singh. 1974. Developing a soyabean dal for India and other countries. World Crops, March/April 1974.

12. Von Oppen, M. 1974. Soybean processing in India: a location study on an industry to come. Intsoy Ser. No. 4. Int. Agr. Pubs. College of Agr. University of Illinois.

13. Williams, S.W., and K.L. Rathod. 1974. A case study of expeller production of soybean flour in India. Intsoy Ser. No. 3. Int. Agr. Pubs. College of Agr. University of Illinois.

DISCUSSION

E.V. DOKU: Am I correct in assuming that you did not obtain any correlation between nodulation and yield because you might have been operating at near optimum nodulation levels?

M. VON OPPEN: No, the populations observed were quite below recommended levels. This finding about the lack of correlation between yield and population requires further investigation, perhaps a respecification of the model.

DOKU: When you have a series of independent varieties which are themselves related, you tend to get funny multiple regression relationships with respect to the dependent variety.

VON OPPEN: I intend to study the data in more detail, especially with respect to different locations, in order to see whether the coefficients found for the aggregate 400 observations hold true also for the various districts individually. It may be that the mysterious result may disappear, implying that there are various local optima, depending upon local conditions.

C.N. HITTLE: How do you account for the fact that fertilizer and yield are not significantly positively correlated when, in central India (in experimental plots), researchers get a tremendous response to phosphorus?

VON OPPEN: Things look different on farmers' fields than they do in experiment stations. But to answer the question, it appears as if fertilizer was given in certain districts while on others it was generally not applied, and that just those districts in one or both of the years under observation faced adverse weather conditions.

Some Important Seed- and Soil-borne Bacterial and Fungal Pathogens of Soybeans

J.B. Sinclair

There are over 50 fungal and five bacterial diseases of soybean, many of which can cause serious losses in seed quality, seedling emergence, plant stands, and yields. Any nation developing soybean as a crop must be aware of the potential of these and other plant pathogens to limit their production. My experience has shown that any given soybean producing area has unique environmental conditions and, similarly, may develop unique disease situations. Also, areas that are placed into soybean production for the first time may be free of many soybean pathogens. Every precaution should be taken to ensure that pathogens not now present in an area are not introduced on seeds, plant debris, and soil.

There are several bacterial and fungal diseases of economic importance from various parts of the world: bacterial blight (*Pseudomonas glycinea*), bacterial seed decay and seedling blight (*Bacillus* spp.), *Rhizoctonia* root and stem decay (*R. solani*), pod and stem blight (*Diaporthe phaseolorum* var. *sojae* and *Phomopsis sojae*), anthracnose (*Colletotrichum truncatum*), charcoal rot (*Macrophomina phaseolina*), and rust (*Phakopsora pachyrhizi*) (1-3,10,27,29).

Bacterial Blight

Bacterial blight is worldwide in distribution and is most common in regions with cool, rainy weather. It is repressed by hot, dry weather. Outbreaks usually occur after wind-rain storms. *P. glycinea* is seedborne and causes a foliage blight and cotyledonary and pod lesions. When seedborne, the bacterium can cause seed decay and reduce germination and emergence (Table 1) (20,22,23,30). *P. glycinea, P. tabaci,* and *Bacillus* spp. can reduce seedling emergence from seeds vacuum-infiltrated with suspensions of these bacteria (Table 2). During routine examination for seedborne organisms in soybean we found that a bacterial growth commonly occurred over the surface of many seeds when surface-sterilized and plated on synthetic media (20,22,23,28). We have considered the bacterium to be *P. glycinea*, but *Bacillus* spp. may also play an important role (F.D. Tenne, S.M. Foor and J.B. Sinclair, unpublished data). *P. glycinea* and/or *Bacillus* spp. were detected in soybean seeds harvested from six states of the United States and India (Table 3) (20-22).

Dadson and Hume (personal communication), University of Ghana, reported a major problem of getting poor emergence of soybeans at high soil temperatures. R.J. Williams (personal communication), International Institute of Tropical Agriculture, Nigeria, reported complete kill of soybean seeds in field trials at Ibadan when seeds were planted in soil temperatures between 33^{o} and 37^{o}C. Similar reports have come from other tropical countries. The effects of the seedborne bacteria on soybean are more severe at incubation and soil temperatures of 30^{o}, 35^{o}, and 40^{o}C than at 20^{o} and 25^{o}C (20-22). It is suggested that most, if not all, soybean seeds carry one or more bacteria and that under conditions of high temperature and moisture, these bacteria can reduce seed germination and emergence.

Rhizoctonia Root and Stem Decay

R. solani causes damping-off, root rot, stem decay, or web blight of hundreds of plant species around the world. The fungus is soilborne and seedborne in soybeans. Most reports describe pre- and post-emergence damping-off as the major disease of soybeans. However, *R. solani* (possibly in combination with *Fusarium* spp. and other soilborne fungi) causes severe losses to maturing soybeans in growing areas of southern Brazil (P.S. Lehman and C.C. Machado, personal communication) (15). Large areas or patches within a field show progressive dying of plants throughout flowering to maturity. Losses up to 40 percent of potential yields were reported (15). This appears to be a unique disease situation that developed after intensive soybean production was started in Brazil.

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Table 1. Correlation between incidence of *Pseudomonas glycinea* in 17 seed lots of Lee 68 soybeans with percentage germination *in vitro* and percentage field emergence at three locations, 1970.

Lot no.[a]	*In vitro* tests[b]		Percentage field emergence				
	Percentage seed with *P. glycinea*	Percentage germination	La.[c] April	La.[c] Oct.	Ky.[d] May	Miss.[e] May	Miss.[e] June
1	22	64	54	13	59	84	27
2	41	63	48	11	54	80	36
3	55	34	11	1	18	38	11
4	52	19	12	5	19	29	12
5	8	90	80	32	85	98	72
6	14	74	73	57	62	85	80
7	35	68	78	69	65	83	78
8	4	96	83	61	88	96	88
9	3	87	83	67	78	95	86
10	11	84	90	56	80	95	88
11	9	81	78	52	71	93	75
12	20	68	70	43	73	88	78
13	8	96	92	69	84	98	87
14	9	91	83	66	81	97	83
15	9	87	72	30	86	96	73
16	64	82	85	38	78	96	77
17	17	89	85	75	86	99	88
Av	23	75	69	44	69	85	67
Correlation coefficient with %P[f]		-.72	-.64	-.61	-.69	-.67	-.65

a/ Lots 1-4 from Louisiana, 5-7 from Mississippi, 8-12 from South Carolina, 13-16 from Texas, and 17 from Illinois.

b/ Based on 108 surface-sterilized seeds/lot assayed for internally borne microorganisms on nine differential media.

c/ Based on four replications of 100 seeds each. Stand counts taken 28 days after planting at Louisiana State University.

d/ Based on six replications of 200 seeds each. Stand counts taken 5 days after planting at University of Kentucky.

e/ Based on six replications of 50 seeds each. Stand counts taken 18 and 22 days after planting for May and June, respectively, at Mississippi State University.

f/ 1% level of significance = -.590.

Table 2. Percentage emergence from 50 Amsoy soybean (*Glycine max*) seeds noninoculated (control) or inoculated by vacuum infiltration with sterile water suspensions of one of three bacteria.

Treatment	Emerence at days after sowing		
	7	11	22
Control	76	80	84
Pseudomonas glycinea	34	40	68
P. tabaci	18	24	38
Bacillus spp.	2	4	38

Table 3. The occurrence of *Pseudomonas glycinea* and fungi in 27 Bragg soybean seed lots collected in Madhya Pradesh, India, and their effect on germination in the laboratory and emergence in greenhouse pots and field plots.

Lot no.[a]	Percentage[b]			Mean emergence[c]	
	P. gly.	Fungi	Germ.	Pothouse	Field
1	6	89	36	40	33
2	5	86	17	12	14
3	9	68	22	8	12
4	5	53	42	28	27
5	8	77	37	38	23
6	61	36	44	39	19
7	36	81	23	10	6
8	47	71	21	8	5
9	57	41	21	18	9
10	42	35	18	8	5
11	38	16	38	34	18
12	6	53	65	44	42
13	9	75	30	28	22
14	3	96	2	2	1
15	11	72	15	3	6
16	3	48	42	20	10
17	4	56	41	15	14
18	6	41	79	28	23
19	16	29	44	5	6
20	4	29	50	16	14
21	16	43	8	6	3
22	22	75	30	18	15
23	14	40	63	49	32
24	25	28	79	61	38
25	8	20	83	53	44
26	31	48	33	30	7
27	55	38	6	6	2
Correlation coefficient with percent *P*[d]		*P. gly.*	-.26	-.09	-.38
		Fungi	-.51	-.33	-.02
		Total organisms	-.70	-.34	-.42

a/ Lots 1-15 from Seoni; 16-21 from Chhindwara; 22-23 from Narsinghpur; 24-25 from Jabalpur; and 26-27 from Panna. Seeds grown in 1971.
b/ Based on 200 seeds, 100 each on Difco potato-dextrose agar or Difco lima bean agar.
c/ Based on four replicates of 100 seeds per replicate.
d/ 5% level of significance = -.38.

Pod and Stem Blight

D. phaseolorum var. *sojae* is worldwide in distribution causing a blight on the pods and stems of soybean and rarely occurring on the foliage. It is seedborne and can live over in soil as a saprophyte. Warm temperatures and heavy rainfall favor the development of the disease, which can cause losses up to 20 percent. This disease does not develop under cool, dry conditions. When seedborne it can reduce germination and seedling emergence (Table 4) (11,18,19,28). The fungus penetrates the seed pod and enters the developing seeds. It first colonizes the hourglass cell layer of the seed coat (Fig. 1), then spreads throughout the seed coat and into cotyledonary tissues (12, 26). In 1970, it was found that Cutler soybean seeds that were delayed in harvest for 30 days, had increased occurrence of *D. phaseolorum* var. *sojae* and reduced germination when compared to earlier harvested seeds (Table 5) (18).

Table 4. Percentage occurrence of *Diaporthe phaseolorum* var. *sojae* (50 seeds/lot), *in vitro* germination (25°C), and field emergence (400 seeds/lot) among 19 Lee 68 soybean seed lots grown in five states in 1970 and stored for 12 months at 3° ± 1°C.

Lot no.	Percentage		
	D. phas.	Germination	Emergence
1	42	52	12
2	87	9	5
3	5	93	58
4	16	61	53
5	19	73	51
6	27	48	34
7	5	81	36
8	23	38	24
9	25	83	41
10	3	98	44
11	6	98	62
12	10	85	64
13	18	95	69
14	4	89	62
15	1	89	61
16	1	95	76
17	0	87	64
18	0	78	46
19	0	76	53
20	0	88	51
Av	14	76	49

Table 5. Percentage (based on 50 seeds/lot) recovery of *Diaporthe phaseolorum* var. *sojae*, and *in vitro* germination (25°C) of Cutler soybean seeds grown in Kentucky and harvested by hand or by machine at two dates 30 days apart, October and November 1970.

Harvest		Percentage	
Method	Date	*D. phas.*	Germination
Hand	October	44	64
Hand	November	60	20
Machine	October	44	84
Machine	November	68	32
Machine	October	28	80
Machine	November	42	40
Machine	October	32	76
Machine	November	52	28

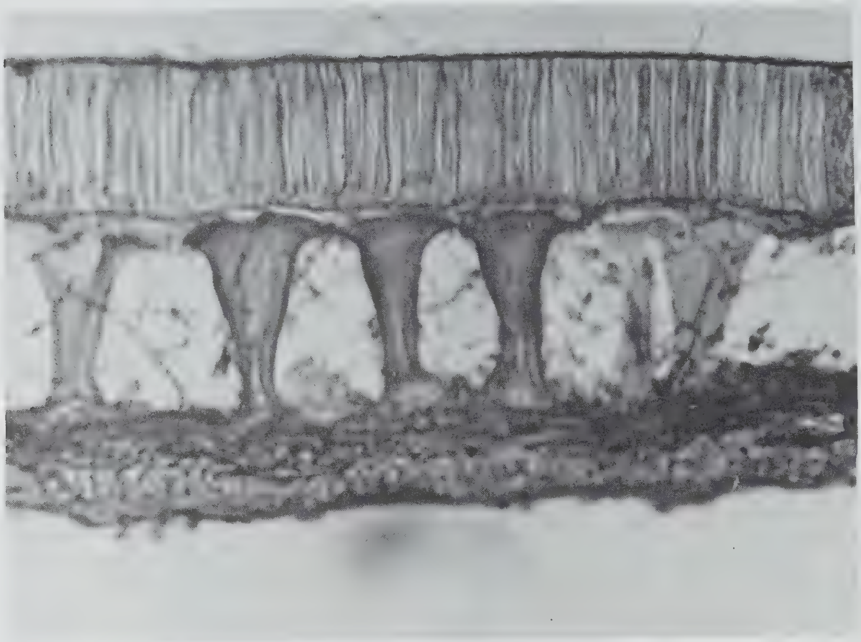

Fig. 1. Location within the soybean (*Glycine max*) seed coat of *Diaporthe phaseolorum* var. *sojae* (*Phomopsis sojae*) mycelium in the palisade (upper), hourglass (middle), and parenchyma (lower) cell layers (X 300).

Anthracnose

C. truncatum (*Glomerella glycines*) causes severe losses in the humid tropics and subtropics with yields reported reduced up to 80 percent in localized areas. Plants are susceptible at all stages. The fungus is seedborne and can reduce the emergence and stands (21). It first colonizes the hourglass cell layer of the seed coat and spreads to other parts of the seed (24). Symptoms on stems and pods appear as definite brown areas on which are formed acervuli. The fungus can live over in infected plant debris. Nicholson et al. (21) showed that soybean seeds harvested during the monsoon season in India had a greater incidence of *C. truncatum* than those harvested at the end of the season (Fig. 2).

Charcoal Rot

M. phaseolina is worldwide in distribution, is seedborne, can attack over 400 species of plants, and can live over in the soil as sclerotia for long periods of time (1-3,10,27,29). The fungus causes a seedling blight, root rot, and lower stem decay (4-9,13,16,17). The disease is most severe under hot, dry conditions. The fungus is highly variable (5,6). The only above-ground symptom may be yellowing and wilting of the foliage of infected plants. However, examination of the lower stem will show a superficial lesion extending from ground level up the stem. When the back is pulled back at the lesion, small black sclerotia can be seen. The tissue has a silvery grey or charcoal appearance. The symptoms are brought about by an interaction of enzymes (4), toxins (7), and intraxylem sclerotia (13) (Fig. 3). Several soil factors influence the survival of sclerotia in the soil (8,9,16,17).

Rust

Soybean rust is found in Indonesia, Russia, India, mainland China, Taiwan, and Australia. It is not now known to occur in the Americas, Africa, the Middle East, or Europe, although reports indicate that it could survive in these areas (K.R. Bromfield, personal communication). All U.S.-developed varieties are susceptible. *P. pachyrhizi* is hemicyclic and attacks a number of other legume species including *Glycine wightii*, *G. javanica*, *G. clandistina*, *G. tabacina*, *G. tomentella*, *Phaseolus lathyroides*, *P. vulgaris*, *Lupinus angustifolius*, *Lespedeza junica*, *Kennedia rubicunda*, *K. coccinia*, and *Canavalia maritima* (14). It causes a foliage blight which is followed by complete defoliation. Seed transmission is suggested. All precautions must be taken to prevent this fungus from being introduced into rust-free areas.

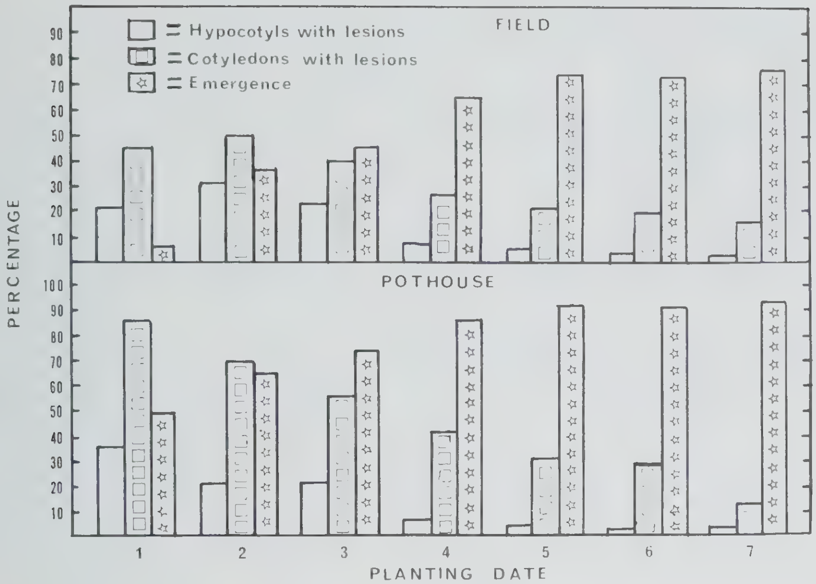

Fig. 2. Effect of seven planting dates (1 = June 1; 2 = June 16; 3 = July 1; 4 = July 16; 5 = July 31; 6 = Aug. 14; 7 = Sept. 2) on occurrence of seedborne *Colletotrichum truncatum* in five soybean varieties (Bragg, Davis, Lee, JB-2, and Pb-1) and effect of seedborne *C. truncatum* on percentage emergence, cotyledons with lesions, and hypocotyls with lesions developing from the infected cotyledons. Percentages based on 1,000 and 2,000 seeds per planting date for pothouse and field trials, respectively. The LSD .05 for field emergence, cotyledons with lesions, and hypocotyls with lesions was 9.2, 9.9, and 4.8, respectively, and for pothouse, 10.9, 12.6, and 5.7 respectively.

Fig. 3. Photomicrograph of longitudinal section of soybean (*Glycine max*) stem inoculated with *Macrophomina phaseolina* showing intraxylem sclerotia (arrows) (X 30).

REFERENCES

1. Caldwell, B.E., ed. 1973. Soybeans: improvement, production and uses. Amer. Soc. Agron., Madison, Wis.

2. Chamberlain, D.C. 1973. Soybean diseases in Illinois. Illinois Ext. Cir. 3085.

3. Chamberlain, D.W., and B.R. Lipscomb. 1967. Bibliography of soybean diseases. U.S. Dept. Agr., ARS, Crops Res. Div. Publ. 50-67.

4. Dhingra, O.D., R.W. Schneider and J.B. Sinclair. 1974. Cellulolytic and pectolytic enzymes associated with virulent and avirulent isolates of *Macrophomina phasealina* in vitro and in soybean seedlings. Phytopath. Z. 80:(in press).

5. Dhingra, O.D., and J.B. Sinclair. 1973. Variation among isolates of *Macrophomina phaseoli (Rhizoctonia bataticola)* from different regions. Phytopath. Z. 76:200-204.

6. Dhingra, O.D., and J.B. Sinclair. 1973. Location of *Macrophomina phaseoli* on soybean plants related to culture characteristics and virulence. Phytopathology 63:934-936.

7. Dhingra, O.D., and J.B. Sinclair. 1974. Isolation and partial purification of a phytotoxin produced by *Macrophomina phaseolina*. Phytopath. Z. 80:35-40.

8. Dhingra, O.D., and J.B. Sinclair. 1974. Effect of soil moisture and carbon:nitrogen ratio on survival of *Macrophomina phaseolina* in soybean stems in soil. Plant Dis. Reptr. 58:(in press).

9. Dhingra, O.D., and J.B. Sinclair. 1975. Survival of *Macrophomina phaseolina* in soil affected by soil moisture, carbon:nitrogen ratios, carbon sources and nitrogen concentrations. Phytopathology 65:(in press).

10. Dunleavy, J.M., D.W. Chamberlain, and J.P. Ross. 1966. Soybean diseases. U.S. Dept. Agr. Handbook No. 302.

11. Ellis, M.A., C.C. Machado, C. Prasartsee, and J.B. Sinclair. 1974. Occurrence of *Diaporthe phaseolorum* var. *sojae* (*Phomopsis* sp.) in various seedlots. Plant Dis. Reptr. 58:173-176.

12. Ilyas, M.B., O.D. Dhingra, M.A. Ellis, and J.B. Sinclair. 1975. Location of mycelium of *Diaporthe phaseolorum* var. *sojae* and *Cercospora kikuchii* in infected soybean seeds. Plant Dis. Reptr. 59:(in press).

13. Ilyas, M.B., and J.B. Sinclair. 1974. Effects of plant age upon development of necrosis and occurrence of intraxylem sclerotia in soybean infected with *Macrophomina phaseolina*. Phytopathology 64:156-157.

14. Keogh, R. 1974. *Phakopsora pachyrhizi* Syd.: the causal agent of soybean rust. Australian Path. Soc. Newsltr. 3(1)5(Abstr.).

15. Machado, C.C., J.C. Gomes, and P.S. Lehman. 1973. Dead patch of soybeans in southern Brazil. 2nd Int. Cong. Plant Path. Abstr. 1062. Minneapolis, Minn.

16. Meyer, W.A., J.B. Sinclair, and M.N. Khare. 1973. Biology of *Macrophomina phaseoli* in soil studied with selective media. Phytopathology 63:613-620.

17. Meyer, W.A., J.B. Sinclair, and M.N. Khare. 1974. Factors affecting charcoal rot of soybean seedlings. Phytopathology 64:845-849.

18. Nicholson, J.F., O.D. Dhingra, and J.B. Sinclair. 1972. Internal seedborne nature of *Sclerotinia celerotorium* and *Phomopsis* sp. and their effects on soybean seed quality. Corrected to read. Internal seed-borne nature of *Diaporthe phaseolorum* var. *sojae* (*Phomopsis* sp.) and their effects on soybean seed quality. Phytopathology 62:1261-1263.

19. Nicholson, J.B., O.D. Dhingra, and J.B. Sinclair. 1973. Soil temperatures and inoculation techniques affect emergence and reisolation of *Sclerotinia celerotorium* from soybean. Corrected to read: Soil temperatures and inoculation techniques affect emergence and reisolation of *Diaporthe phaseolorum* var. *sojae* from soybean. Mycopath. Mycol. Appl. 50:179-182.

20. Nicholson, J.B., and J.B. Sinclair. 1971. Amsoy soybean seed germination inhibited by *Pseudomonas glycinea*. Phytopathology 61:1390-1393.

21. Nicholson, J.B., and J.B. Sinclair. 1973. Effect of planting date, storage conditions, and seed-borne fungi on soybean seed quality. Plant Dis. Reptr. 57:770-774.

22. Nicholson, J.B., J.B. Sinclair, and L.K, Joshi. 1973. Seed-borne *Pseudomonas glycinea* and fungi affect soybean seed in India. Plant Dis. Reptr. 57:531-533.

23. Nicholson, J.B., J.B. Sinclair, and J.C. White. 1974. Survival and entry of *Pseudomonas glycinea* into soybean seed. Phytopath. Z. 78:357-364.

24. Schneider, R.W., O.D. Dhingra, J.F. Nicholson, and J.B. Sinclair. 1974. *Colletotrichum truncatum* borne within the seedcoat of soybean. Phytopathology 64:154-155.

25. Schneider, R.W., P.N. Thapliyal, and J.B. Sinclair. 1971. Fungi associated with soybean seed from India. Indian Phytopath. 24:792-794.

26. Sinclair, J.B. 1974. The role of the seed coat in disease control of soybeans. Proc. 9th Ann. Illinois Soybean Conf. 22. Illinois Crop Improvement Assn., Urbana.

27. Sinclair, J.B., and L.E. Gray. 1972. Three fungi that can reduce soybean yields. Illinois Agr., Winter 1972, p.5.

28. Tenne, F.D., C. Prasartsee, C.C. Machado, and J.B. Sinclair. 1974. Variation in germination and seed-borne pathogens among soybean seedlots from three regions in Illinois. Plant Dis. Reptr. 58:411-413.

29. United States Regional Soybean Laboratory. 1973. Rpt. 2nd national soybean research conference. RSLM 775. U. S. Regional Soybean Laboratory, Urbana, Ill.

30. White, J.C., J.F. Nicholson, and J.B. Sinclair. 1972. Effect of soil temperature and *Pseudomonas glycinea* on emergence and growth of soybean seedlings. Phytopathology 62:296-297.

DISCUSSION

S.D. AGBOOLA: How do you score on the field for bacterial diseases (say pustule of soybean) in an attempt to assess yield losses?

J.B. SINCLAIR: It is difficult to screen soybeans to various diseases in the field, if a disease occurs naturally. This type of work needs to be done in controlled conditions.

M. WOLDE: In our research with soybeans we have observed in many cases a disease called downy mildew where a long, thin mycelium is observed. But so far this disease is not mentioned. Isn't it a common soybean disease in most parts of the world?

SINCLAIR: It is a common disease. We do not have time to discuss all the diseases of soybeans.

R.B. DADSON: With regard to the seed, some diseases and interaction with soil temperature and seedling emergence--is there any beneficial effect with seed dressing?

SINCLAIR: Seed dressings such as Captan and Thiram control the fungal diseases, but not the bacterial diseases.

B. STEELE: Emphasis has been placed on the seedborne aspects of the diseases described. Are there not many field transmitted diseases also?

SINCLAIR: Yes, among those pathogens mentioned that are soilborne are *Rhyzoctonia solani, Macrophomina phaseolina, Colletotrichum trancatum,* and others.

Important Nematode and Virus Diseases of Soybeans

R.M. Goodman

Nematode Diseases

The potential for growing soybeans in tropical countries, where the need for high-quality protein in human diets is greatest, has been clearly established. Results of variety trials in many tropical areas show that soybeans can be grown successfully. Full realization of the potential of soybeans to help alleviate the critical shortage of protein and oils needed for human consumption will depend on many factors. By no means the least of these will be the diseases that can limit soybean production or prevent it altogether. Several serious diseases of soybeans are known from our experience in temperate areas, e.g., soybean rust and the soybean cyst nematode. As more soybeans are grown in tropical areas we must be prepared to discover and overcome other diseases as yet unknown, as well as to deal in a new context with diseases already known that may be unusually severe in tropical areas. I shall review here the causes and consequences of nematode and virus diseases of soybeans and attempt to identify the areas of soybean pathology research that need to be strengthened to meet the problems we expect to confront as research on and development of soybeans for the tropics progresses.

It is an accurate generalization that nematode and virus diseases become progressively more important as one moves from temperate to tropical regions. And while several nematode and virus diseases of soybeans are important in temperate regions, only one, the soybean cyst nematode, is a serious problem in major soybean producing areas. The soybean cyst nematode *(Heterodera glycines)* causes infected soybeans to be stunted and yellow. In severe cases, when other conditions are unfavorable, infected plants die prematurely and loss of an entire crop is possible. Symptoms that can be seen on the above-ground parts of plants are not sufficient to allow a positive diagnosis of this disease because similar symptoms can be caused by other root pathogens or abiotic conditions. Diagnosis requires examination of the roots, recovery of the nematode from the roots or soil, and study of the pathogen with a microscope by a trained plant nematologist (38).

Plant roots are infected by a juvenile form of the nematode, a very small, worm-like animal that penetrates the root. Once inside, the nematode feeds and develops in the pericycle, causing the formation of giant cells and the partial loss of efficient root function. This activity has also been shown to be antagonistic to *Rhizobium* infection (3). The adult female nematode enlarges to form a lemon or flask shape which eventually breaks through the root surface. Eggs are produced by the female during development of this enlarged form. Most of the eggs remain enclosed in the female nematode's body that appears as a white, spherical protrusion attached to the surface of the root. After the female nematode dies the carcass turns yellow and then brown and becomes a protective case or cyst containing many yellow eggs. The cysts remain in the soil after death of the plant, and the eggs within can remain viable for many years. The cyst is readily spread by movement of soil by man and by wildlife.

Cysts can even be ingested by birds (21) or swine (50) and when later eliminated, perhaps in a field that is not yet infested, the eggs may still be alive. Thus the cyst form allows the nematode to spread as well as to resist dry or cold seasons when no host plant is available. High populations of the cyst nematode in fields where soybeans are grown can result in significant loss of yield, even when other conditions for soybean growth are good; under adverse conditions heavy infection by the cyst nematode can result in very severe losses.

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The soybean cyst nematode is limited to certain areas of the world where soybeans have long been grown. These include parts of China, Japan, Manchuria, Korea, and the United States (27). The soybean cyst nematode has also been reported recently from Egypt (20). Surveys should be made by a trained nematologist in areas where soybeans will be grown for the first time, to establish whether the soybean cyst nematode is present. Countries or areas free of this nematode should be especially careful to prevent introducing it with seeds, machinery, or other imported items that may contain infested soil. Such vigilance should be a high priority of the agricultural scientists of any country experimenting with soybeans.

In areas where soil is infested with the soybean cyst nematode, soybeans can be grown only if measures are taken to keep nematode populations at a low level. Various nematicides have been developed that are effective, but they are prohibitively expensive and require application each year. The only satisfactory means for control of this pathogen are use of resistant varieties and crop rotation. Several sources of resistance are known and these have been incorporated into commercial soybean varieties (10, 22, 34, 49). However, the use of resistant varieties in the United States has shown that physiological races or strains of *H. glycines* exist, and that varieties of soybean resistant to one race may not necessarily be resistant to other races (45). Continual monitoring of the soil where resistant varieties are growing is therefore necessary to detect increases in the population of any new races of the cyst nematode that may occur. Crop rotation with nonhost plants such as cowpea, maize, cotton, and milo has been shown to reduce cyst nematode populations in two-, three-, or four-year rotations with soybeans (25, 44). However, susceptible weeds and volunteer plants must be eradicated effectively for control of this nematode by crop rotation to be successful.

While I have emphasized the importance of the soybean cyst nematode, other nematodes may be just as important in tropical areas. Nematodes of more than 20 different kinds have been reported associated with soybeans throughout the world (22, 23, 25). Not much specific information about the importance of most of these nematodes to soybeans is yet available. The root-knot nematodes *(Meloidogyne incognita, M. javanica,* and other species) are widely distributed throughout the subtemperate to tropical latitudes of the world. Root-knot nematode larvae invade susceptible plants near the growing root tip and cause the formation of large root galls or knots. The effect of root-knot nematode infection on the plant is to reduce root efficiency so that even in soils containing adequate moisture and minerals the plants may turn yellow and wilt. Plants become stunted, yield is reduced, and in severe cases crop loss may result. The entry of root-knot nematodes into susceptible roots can also increase the likelihood that other root pathogens such as fungi and bacteria will gain entry to the root.

Generally, the root-knot nematodes have rather wide host ranges. Tropical soils in which soybeans have never before been grown may contain high levels of this or other soybean nematode pathogens. Therefore, research emphasis must be placed on surveys to determine what indigenous nematodes are present, tests to establish the importance of these pathogens to soybean varieties, and trials to determine appropriate crop rotation methods for controlling these nematodes. For control of the root-knot nematodes a few resistant varieties are available (16, 22). Sun hemp *(Crotolaria)* and oats can be used as nonhosts in crop rotation schemes (22). However, as soybean production is increased in tropical areas infested with the root-knot nematode, various crops of local interest should be tested for their suitability as nonhosts in crop rotation schemes. Because the root-knot nematodes have no cyst form to enable them to survive long periods in the absence of host plants, clean fallow may be useful to, in effect, starve the nematodes between plantings of susceptible crops (15).

Another nematode affecting soybeans that is of potential importance in the tropics is the reniform nematode *(Rotylenchulus reniformis)*. Soybeans have been reported to be a good host of the reniform nematode in such diverse locations as the southern United States (6), Brazil (33), and Ghana (41). Several studies on the factors affecting disease development have been published (43). Again, the use of resistant varieties is the method of choice for control of this nematode. Some varieties resistant to the soybean cyst and/or the root-knot nematode are also resistant to the reniform nematode (42).

Other nematodes that can cause diseases of soybeans and that are widespread in tropical soils but are less well studied include the lesion nematodes *(Pratylenchus* spp.), spiral nematodes *(Helicotylenchus* spp.), and lance nematodes *(Hoplolaimus* spp.). Sting

nematodes (*Belonolaimus* spp.) can severely damage soybeans, but these nematodes appear to be restricted to the southern United States at present.

Knowledge about the ability of many tropical nematodes to cause diseases of soybeans is not yet available. The discussion presented here reflects in its emphasis the diseases that are of importance in areas of the world where soybeans have been grown extensively. It may well be that important new soybean diseases heretofore unreported may be caused by nematodes found in tropical soils.

This discussion of known nematode diseases of soybeans should establish several general truths, however, regardless of the importance of the specific diseases discussed. First, many species of nematodes that are known to thrive in tropical soils can cause diseases of soybeans, and in some cases these can be very severe. Second, the disease caused by the soybean cyst nematode is a particularly intractable problem in areas where the cyst nematode occurs. All precautions should be taken by countries free of this nematode to prevent introducing it. Third, the only economically feasible methods now available for control of soybean diseases caused by nematodes are rotation with nonhost crops and use of resistant varieties. It is therefore important that knowledge be available about the host range of indigenous nematodes so that appropriate crop rotation schemes can be designed. We also need to know what nematodes are indigenous to tropical areas where soybeans will be grown and whether they will infect soybeans, so that new or newly introduced soybean varieties can be screened for nematode resistance. Both of these needs will require the services of a plant pathologist trained in nematology who is familiar with the agricultural practices, the prevalent weeds, and the crops of each locality where soybean research and development is planned.

It seems to me appropriate to end this discussion of soybean nematode diseases with some comments on the sources of information about plant nematology and to mention some of the more prominent research workers in the United States who are concerned with nematodes that attack soybeans. Plant nematologists publish research papers in such journals as Phytopathology, Plant Disease Reporter, Nematologica, Journal of Nematology, Indian Journal of Nematology, Annals of Applied Biology, Proceedings of the Helminthological Society of Washington, Nematropica, and the Netherlands Journal of Plant Pathology. The Helminthological Abstracts Series B--Plant Nematology is a useful abstracting source for information on papers published in this area. Two useful books on tropical nematology are those by Peachy (40) and Smart and Petty (51).

Professional societies specifically concerned with plant nematology are the Society of Nematologists (United States), the European Society of Nematologists, the Organization of Tropical American Nematologists, and the Association of Applied Biologists (United Kingdom).

The major centers of plant nematology research have been England, Holland, and the United States. Most research on soybean nematodes has been conducted in the United States. D. I. Edwards, University of Illinois and United States Department of Agriculture; J. M. Epps, University of Tennessee and United States Department of Agriculture; and J. P. Ross, North Carolina State University and United States Department of Agriculture; are the leading U.S. plant pathologists doing research on soybean nematodes.

Virus Diseases

With the possible exception of the soybean rust and soybean cyst nematode diseases, the most serious disease threat to soybean production in the tropics is posed by virus diseases. Most of the known soybean viruses that are of any consequence are transmitted by insects, and this we expect to be true in the tropics as well. Some soybean viruses are seed transmitted while others are not. But the prevalence in tropical areas of insect vectors of other legumes both as crops and as weeds, and the absence of a winter season, all contribute to our expectation that virus diseases will be a significant factor in determining the success or failure of soybeans in the tropics. We at the International Soybean Program are giving high priority to assembling information on soybean viruses of potential importance in the tropics and to careful screening of new varieties for susceptibility or resistance to the important soybean viruses.

The virus diseases of soybeans fall into two categories; those caused by conventional viruses and not transmitted by whiteflies, and those the causal agents of which are not yet established for certain and that are transmitted by whiteflies. The most common virus of soybeans in temperate regions is soybean mosaic virus (SMV). This virus is transmitted nonpersistently by several different species of aphids and is also transmitted through

the seed. It can be readily transmitted mechanically. There is a wide range of symptoms of this disease depending upon soybean variety, weather, time of inoculation, and strain of the virus (48). A mild strain of SMV in tolerant varieties growing under ideal conditions may cause little loss of yield, although maturity of the plants may be delayed. In warm climates (above 30°C) plants may grow normally with few foliar symptoms. Highly susceptible varieties or moderately susceptible varieties infected with severe strains of SMV may show a yellow veinclearing symptom followed by characteristic mosaic and rugosity. Severely affected plants may be stunted with short internodes and downwardly curled leaves, and the pods may contain fewer than the normal number of seeds. Yield reduction of 25 percent in single infections and 80 percent in double infections with bean pod mottle virus have been reported (47). Soybean mosaic virus is seed transmitted and is therefore known in every country where soybeans have been grown (18). Most commercial seedlots of soybeans contain some SMV-infected seeds; some varieties have a very high level of seed transmission (19, 52). The host range of SMV was originally thought to be very narrow. Results of more recent studies show that a wide range of legumes is susceptible.

In addition to the deleterious effect on plant growth and yield, some soybean varieties infected with SMV produce mottled seed--that is, seed having an irregularly pigmented seed coat. This is considered to be an undesirable character in the soybean seed industry. Resistance to seed mottling and tolerance to SMV infection are available in certain soybean varieties. It is theoretically possible to control SMV by planting noninfected seed of resistant varieties and controlling insect vectors, but, in practice, control of insect vectors is not effective.

Two viruses are known that can cause bud blight diseases of soybeans. Tobacco streak virus (TSV) causes a severe bud blight disease in Brazil (14) and the United States (24). The more common bud blight disease in the United States is caused by tobacco ringspot virus (TRSV). Both TSV and TRSV have very wide host ranges. No insect vector is known for TSV, and the means of spread in soybeans is unknown. Tobacco streak virus was recently reported to be seed-transmitted in soybeans (27a). Field spread of TRSV is probably by thrips (35). TRSV can also be transmitted by grasshoppers (17) and by nematodes of the genus *Xiphinema* (5), although in both cases transmission of TRSV to soybeans is very inefficient. The extent of seed transmission of TRSV in soybeans is variable (2) but it can be an important means of spread of the disease. Athow and Bancroft (1) obtained 100 percent seed transmission of TRSV from plants that became infected before flowering.

The symptoms of TSV and TRSV infection of soybeans are identical. The growing tip of young infected plants curves downward and becomes brown and dies. The plants are therefore stunted and produce little or no seed. Leaves of infected plants often show a red flecking symptom. When plants become infected during or after flowering the seed is borne in poorly developed pods that often show dark irregular markings. As with soybean mosaic virus, TRSV causes infected soybeans to mature later than healthy plants so that at the end of the growing season, when healthy plants lose their leaves, virus infected plants remain green.

Another soybean disease of special importance in southern areas of the United States is that caused by bean pod mottle virus (BPMV). Yield reductions caused by BPMV alone are not generally serious, although seed size may be reduced; but when BPMV and SMV doubly infect soybeans the losses are very serious (8, 4). Foliar symptoms of BPMV consist of a mild chlorotic mottle that may be marked at high temperatures. The virus has a very narrow host range but it includes several other useful bean crops in the genus *Phaseolus*. BPMV is transmitted in soybean fields by beetles (39, 46, 54) and can also be transmitted mechanically.

Alfalfa mosaic virus (AMV) (Lucerne mosaic virus) has also caused disease in soybeans in Japan, South Africa, and the United States (18), although the symptoms are generally very mild. AMV has a wide host range among the legumes (28, 29) and is probably a common virus in tropical areas where soybeans may become an important crop. Since AMV is transmitted by aphids there is a real possibility that in certain tropical areas a severe strain of AMV may become widespread in soybeans.

Another legume virus that has been reported as a pathogen of soybeans in several countries is bean yellow mosaic virus (BYMV). The English terminology in current use for various yellow mosaic diseases of beans is very confusing. Yellow mosaic diseases have been reported in India, Brazil, and Puerto Rico that are not caused by BYMV but by a

whitefly-transmitted viruslike agent. Bean yellow mosaic virus is a flexuous rod-shaped virus that can be readily purified. It is transmitted in the fields by aphids and can also be mechanically transmitted. It is not seed transmitted. BYMV is recorded as a pathogen of soybeans in the United States (55), Japan (29), and Puerto Rico (J. Bird, personal communication). This virus is widespread in legumes and will undoubtedly appear in soybeans growing in tropical areas.

Soybeans infected by BYMV have yellow mottled foliage or chlorotic veinbanding. Red necrotic areas occur on mature leaves. There are no records on yield loss caused by BYMV in temperate areas, and usually infected plants are not significantly stunted. However, strains of BYMV are known and the potential for a more severe disease of soybeans caused by BYMV is present in tropical areas.

Yet another legume virus that may be important in certain areas of the tropics is soybean dwarf virus (SDV). SDV causes a severe disease first found in the Hokkaido district of Japan in 1952 (53). The known host range is restricted to legumes. SDV is transmitted by aphids in a persistent manner but has not been transmitted mechanically and is not apparently seedborne. There is evidence that SDV may be a phloem-restricted virus. All 45 soybean varieties tested by Tamada (53) were susceptible. SDV is probably related to bean leaf roll virus that occurs in England in field beans (*Vicia faba*) (A. Cockbain, personal communication).

Several other viruses are potentially important in tropical areas if soybeans are grown there, but they are generally of little or no known importance in regions where soybeans have been grown to date. Thus cowpea chlorotic mottle virus, peanut mottle virus, southern bean mosaic virus, and broad bean mottle virus have been reported as pathogens of soybeans in the United States or England (4, 30, 31, 32) but their importance as serious diseases of soybeans in nature has not been established.

Perhaps the greatest threat to soybean production in the tropics is the group of viruslike agents of legumes that are transmitted by whiteflies. Unlike the viruses discussed above, the whitefly-transmitted viruslike agents have not been purified, characterized, or even visualized. But they are serious. J. Bird and his colleagues at the University of Puerto Rico have shown that the agent causing a disease of a common leguminous weed, *Rhynchosia minima*, causes a severe yellow stunt mosaic disease of soybeans that is very frequently encountered in research trials in Puerto Rico (9). The agent is probably a virus, and is transmitted by a whitefly, *Bemesia tabaci* race *sidae* (8). This disease is probably related to the yellow mosaic of *Phaseolus lunatus*, reported from India (8, 11), mung yellow mosaic virus in India (36, 37), the golden mosaic of *P. vulgaris* in Brazil (13), and the mosaic of *P. longepedunculatus* in Brazil (8, 26). The *Rhynchosia* mosaic agent in Puerto Rico also causes important diseases of other crops, including pigeon peas (*Cajanus cajan*), beans (*Phaseolus* spp.), okra, and tobacco. It is apparently the same agent that causes severe leaf curl diseases of tobacco in Sumatra, Africa, and India (8). The symptoms on soybean include a severe rugose mosaic and stunting.

Another whitefly-transmitted virus that can infect soybeans is *Abutilon* mosaic virus (12). No assessment has been made of the importance of this disease in soybeans in the field. A related disease of *Sida carpinifolia*, also transmitted by *B. tabaci* race *sidae*, occurs in Puerto Rico (7).

The need for sources of high-quality protein in the diet of two-thirds of the human race is critical, and the contribution that soybeans can make to alleviate the shortage of foodstuffs is clearly established. For many reasons--political, social, and economic--it makes sense to grow this valuable crop near the place where need is greatest--the tropical areas of the globe. Unfortunately we must take into account the fact that crops grown in tropical areas are exposed to many more chances of virus infection. As the discussion presented here shows, there are a wide variety of soybean virus diseases and of vectors to spread them. Again, we have talked primarily about the diseases that occur in temperate areas. Some of these diseases will no doubt be more important in the tropics than in temperate zones. In addition, the tropics harbor virus diseases which we have only vaguely glimpsed in this discussion. So there is much work to be done.

We at INTSOY and our INTSOY collaborators around the world are confident that soybeans can be grown successfully in many tropical areas. It is, of course, true that in any one area only a few of these diseases will be important. Our task is to find out which ones, and to develop varieties and cultural practices that will be appropriate for each new situation. To do this we need to cooperate, to exchange information freely, and to ask for help when it is needed.

One way in which people who live in tropical areas and who work with soybeans can help us is to call to our attention potentially serious disease problems when they are noticed. INTSOY proposes to establish a series of soybean disease trials in representative locations around the world where the potential for soybean production has been demonstrated and where a plant pathologist is available to cooperate. With materials supplied by INTSOY and with the assistance of INTSOY plant pathology personnel, cooperators will plant a few of the more promising soybean varieties in trial plots large enough to give a good indication of the diseases, especially virus diseases, that may be important factors in development of soybeans as productive crop in each locality. These trials could be expanded to cover insect pests and vectors also. As the INTSOY and the various national soybean development programs grow, the results of these disease trials will be used directly in breeding programs and in the development of suitable cultural practices. Plans for these trials are in an embryonic state, but I encourage interested pathologists or entomologists to correspond with me about our plans.

Acknowledgments

R. B. Malek, University of Illinois, provided assistance in reading the section on nematodes. Illustrations used in the presentation on nematodes were provided by D. I. Edwards. Several illustrations used in the discussion of soybean diseases caused by viruses were provided by G. M. Milbrath.

REFERENCES

1. Atkow, K.L., and J.B. Bancroft. 1959. Development and transmission of tobacco ringspot virus in soybean. Phytopathology 49:697-701.

2. Atkow, K.L., and F.A. Laviolette. 1962. Relation of seed position and pod location to tobacco ringspot virus seed transmission in soybean. Phytopathology 52:714-715.

3. Barker, K.R., D. Huisingh, and S.A. Johnston. 1972. Antagonistic interaction between *Heterodera glycines* and *Rhizobium japonicum* on soybean. Phytopathology 62:1201-1205.

4. Bawden, F.C., R.P. Chauduri, and B. Kassanis. 1951. Some properties of broad-bean mottle virus. Ann. Appl. Biol. 38:774-784.

5. Bergeson, G.B., K.L. Athow, F.A. Laviolette, and S.M. Thomasine. 1964. Transmission, movement, and vector relationships of tobacco ringspot virus in soybeans. Phytopathology 54:723-728.

6. Bird, G.W., J.L. Crawford, and N.E. McGlohon. 1973. Distribution, frequency of occurrence and population dynamics of *Rotylenchulus reniformis* in Georgia. Plant Dis. Reptr. 57:399-401.

7. Bird, J. 1958. Infectious chlorosis of *Sida carpinifolia* in Puerto Rico. Univ. Puerto Rico Agr. Exp. Sta. Technical Paper 26, pp. 1-23.

8. Bird, J., and J. Sanchez. 1971. Whitefly-transmitted viruses in Puerto Rico. J. Agr. Univ. Puerto Rico 55:461-467.

9. Bird, J., J. Sanchez, and R.L. Rodriquez. 1974. Viruses affecting soybeans in Puerto Rico. Proc. Workshop on Soybeans for Tropical and Subtropical Conditions. INTSOY Pub. 2, pp. 109-111.

10. Caldwell, B.E., C.A. Brim, and J.P. Ross. 1960. Inheritance of resistance of soybeans to the cyst nematode, *Heterodera glycines*. Agron. J. 52:635-636.

11. Capoor, S.P., and P.M. Varma. 1948. Yellow mosaic of *Phaseolus lunatus* L. Current Sci. 17:152-153.

12. Costa, A.S. 1955. Studies on *Abutilon* mosaic in Brazil. Phytopath. Z. 24:97-112.

13. Costa, A.S. 1965. Three whitefly-transmitted virus diseases of beans in Sao Paulo, Brazil. FAO Plant Protec. Bull. 13, pp. 121-130.

14. Costa, A.S., and A.M.B. Carvalho. 1961. Studies on Brazilian tobacco streak. Phytopath. Z. 42:113-138.

15. Crittenden, H.W. 1953. Effect of clean fallow in root knot development on soybeans. Phytopathology 43:405 (Abstr.).

16. Crittenden, H.W. 1954. Factors associated with root-knot nematode resistance in soybeans. Phytopathology 44:388 (Abstr.).

17. Dunleavy, J.M. 1957. The grasshopper as a vector of tobacco ringspot virus in soybean. Phytopathology 47:681-682.

18. Dunleavy, J.M. 1973. Viral diseases. In B.E. Caldwell, ed., Soybeans: improvement, production, and uses. American Society of Agronomy, Madison, Wis.

19. Dunleavy, J.M., S.S. Quiniones, and C.J. Krass. 1970. Poor seed quality and rugosity of leaves of virus-infected Hood soybeans. Phytopathology 60:883-886.

20. Elmiligy, I.A. 1968. The occurrence of *Heterodera glycines* on *Trifolium alexandrum* in the United Arab Republic. Nematologica 14:592-593.

21. Epps, M.M. 1972. Recovery of soybean cyst nematodes from the digestive tract of blackbirds. Tenn. Farm and Home Sci. Prog. Rpt. 81, pp. 2-3.

22. Epps, J.M. 1974. Soybean nematodes. Proc. Workshop on Soybeans for Tropical and Subtropical Conditions. INTSOY Pub. 2, pp. 115-123.

23. Epps, J.M., D.I. Edwards, J.M. Good, and R.V. Rebois. 1973. Annotated bibliography of nematodes of soybeans 1882-1968. U.S. Dept. Agr., Agr. Res. Serv. Pub. ARS-S-8.

24. Fagbenle, H.H., and R.E. Ford. 1970. Tobacco streak virus isolated from soybeans, *Glycine max*. Phytopathology 60:814-820.

25. Ferris, V.R., and R.L. Bernard. 1958. Plant parasitic nematodes associated with soybeans in Illinois. Plant Dis. Reptr. 42:798-801.

26. Flores, E., and K. Silberschmidt. 1966. Studies on a new virus disease of *Phaseolus longepedunculatus*. Anais da Academia Brasileira de Ciencia 38:327-334.

27. Frohlich, G., and W. Rodewald. 1960. Pests and diseases of tropical crops and their control. Pergamon Press, New York.

27a. Ghanekar, A.M., and F.W. Schwenk. 1974. Seed transmission and distribution of tobacco streak virus in six cultivars of soybeans. Phytopathology 64:112-114.

28. Klesser, P.J. 1961. The virus diseases of *Crotalaria, Glycine* and *Medicago* species. Bothalia 7:497-519.

29. Koshimizu, Y., and N. Iizuka. 1963. Studies on soybean virus diseases in Japan. Tohoku (Japan) Natl. Agr. Exp. Sta. Bull. 27, pp. 1-103.

30. Kuhn, C.W. 1963. Field occurrence and properties of the cowpea strain of southern bean mosaic virus. Phytopathology 53:732-733.

31. Kuhn, C.W. 1968. Identification and specific infectivity of a soybean strain of cowpea chlorotic mottle virus. Phytopathology 58:1441-1442.

32. Kuhn, C.W., J.W. Demski, and H.B. Harris. 1972. Peanut mottle virus in soybeans. Plant Dis. Reptr. 56:146-147.

33. Lordello, L.G.E. 1955. Nematodes attacking soybeans in Brazil. Plant Dis. Reptr. 39:310-311.

34. Matson, A.L., and L.F. Williams. 1965. Evidence of a fourth gene for resistance to the soybean cyst nematode. Crop Sci. 5:477.

35. Messieha, M. 1969. Transmission of tobacco ringspot virus by thrips. Phytopathology 59:943-945.

36. Nene, Y.L. 1972. A survey of viral diseases of pulse crops in Uttar Pradesh. University Press, Pantnagar, India.

37. Nene, Y.L. 1973. Viral diseases of some warm weather pulse crops in India. Plant Dis. Reptr. 57:463-467.

38. Oostenbrink, M. 1960. The genus *Heterodera*. In I.N. Sasser and W.R. Jenkins, eds., Nematology. Univ. North Carolina Press, Chapel Hill.

39. Patel, V.C., and H.N. Pitre. 1971. Transmission of bean pod mottle virus to soybean by the striped blister beetle, *Epicauta vittata*. Plant Dis. Reptr. 55:628-629.

40. Peachy, J.E., ed. 1969. Nematodes of tropical crops. Commonwealth Agr. Bur. Commonwealth Bur. of Helminthology, St. Albans, Herts, England.

41. Peacock, F.G. 1956. The reniform nematode in the Gold Coast. Nematologica 1:307-310.

42. Rebois, R.V., J.M. Epps, and E.E. Hartwig. 1970. Correlation of resistance in soybeans to *Heterodera glycines* and *Rotylenchulus reniformis*. Phytopathology 60:695-700.

43. Rebois, R.V., and W.C. Johnson. 1973. Effect of *Rotylenchulus reniformis* on yield and nitrogen, potassium, phosphorus and amino acid content of seed of *Glycine max*. J. Nematol. 5:1-6.

44. Ross, J.P. 1962. Crop rotation effects on the soybean cyst nematode population and soybean yields. Phytopathology 52:815-818.

45. Ross, J.P. 1962. Physiological strains of *Heterodera glycines*. Plant Dis. Reptr. 46:766-769.

46. Ross, J.P. 1963. Transmission of bean pod mottle virus in soybeans by beetles. Plant Dis. Reptr. 47:1049-1050.

47. Ross, J.P. 1968. Effect of single and double infections of soybean mosaic and bean pod mottle viruses on soybean yield and seed characters. Plant Dis. Reptr. 52:344-348.

48. Ross, J.P. 1969. Pathogenic variation among isolates of soybean mosaic virus. Phytopathology 59:829-832.

49. Ross, J.P., and C.A. Brim. 1957. Resistance of soybeans to the soybean cyst nematode as determined by a double-row method. Plant Dis. Reptr. 41:923-924.

50. Smart, G.C., Jr. 1963. Survival of encysted eggs and larvae of the soybean cyst nematode, *Heterodera glycines*, ingested by swine. Phytopathology 53:889-890 (Abstr.).

51. Smart, G.C., Jr. and V.G. Perry, eds. 1969. Tropical nematology. University of Florida Press, Gainesville, Fla.

52. Smith, K.M. 1957. A textbook of plant virus diseases. 2nd ed. Little, Brown and Co., Boston.

53. Tamada, T. 1970. Aphid transmission and host range of soybean dwarf virus. Ann. Phytopath. Soc. Japan 36:266-274.

54. Walters, H.J. 1964. Transmission of bean pod mottle virus by bean leaf beetles. Phytopathology 54:240.

55. Zaumeyer, W.J., and H.R. Thomas. 1957. A monographic study of bean diseases and methods for their control. U.S. Dept. Agr. Tech. Bull. 868, pp. 1-255.

DISCUSSION

W.J. KAISER: During a recent trip to IITA, Ibadan, Nigeria, we were shown lima beans (*Phaseolus lunatus*) that were infected with a disease that produced yellow mosaic symptoms, the vector of which appeared to be whiteflies (*Bemisia tabaci*). Studies are being conducted by R. Williams, IITA, to determine the etiology, host range, vector, transmission, and so on, of this disease. If the disease is shown to be transmitted by whiteflies and to infect naturally disease. If the other food legumes commonly cultivated in Africa, great care should be taken to restrict its movement into other African countries. This is one important reason why food legumes should be distributed between countries as seeds and not as vegetative material, because some potentially important diseases, such as those transmitted by whiteflies, are not known to be seedborne but could be introduced into new areas in vegetative cuttings.

D.B. STEELE: Is the soybean cyst nematode sufficiently host-specific to soybeans that it is unlikely to occur where soybeans have not previously been cultivated?

R.M. GOODMAN: The soybean cyst nematode is highly host specific, but other crop plants are known that support soybean cyst nematode populations in infested soil. Among these are wild soybeans (*Glycine ussuriensis*), vetch (*Vicia sativa*), snap beans (*Phaseolus vulgaris*), mung bean (*P. aureus*), and adzuki bean (*P. angularis*). Cowpeas, however, are highly resistant to soybean cyst nematode.

It does not necessarily follow that soybean cyst nematode could not occur in areas where soybeans have not been grown before. Imported plant material from areas infested with soybean cyst nematode could be infested with cysts. Countries planning to begin or to increase soybean production should be careful not to import plant material or other items that contain soil that might be contaminated.

A. CAMERMAN: In Rwanda, on low-fertility soils infested by nematodes, tolerance to the infestation has been obtained through the use of farmyard manure (plowed down just before planting). This treatment yielded 1,000 kg/ha of soybeans, compared to no yield on the control plot. Have you observed such a beneficial effect of farmyard manure?

GOODMAN: I have had no personal experience of such an effect. It is true, however, that the effects of nematode infection on soybeans growing in lightly infested soils are greater on poor soils or when other conditions are unfavorable than when conditions are favorable.

S.D. AGBOOLA: Please, could you go over the point you were making about the effects of the soybean cyst and root-knot nematodes on the nodulation potentials of the plant?

GOODMAN: Soybean cyst nematode infection of soybean roots has been shown to be antagonistic to the establishment of the *Rhizobium*-soybean symbiosis (Barker et al., Phytopathology 62:1201 (1972).

Infection of some plants by root-knot nematodes is known to increase the likelihood of secondary root pathogen attack, but no such studies have been done with soybeans. When infection by root-knot nematodes is heavy, as in the illustration I gave, we might expect the resulting decrease in healthy root area to be accompanied by a reduction in nodulation, but this has not, to my knowledge, been carefully studied.

Some Aspects of Soybean Entomological Work in Madhya Pradesh, India

G.A. Gangrade

The origin of soybean is lost in antiquity, although it has a comparatively long history bordering on its being a native of China. However, the fantastic achievements during the last 20 years in the development of high-yielding varieties, their production, and utilization in the United States have been responsible for the increase in acreage and steady expansion of soybean in other parts of the world. Presently the United States enjoys predominant position in the cultivation of soybeans with 54 to 58 million acres, raising almost 60 percent of the world production.

The entry of soybean into Indian agriculture is rather recent, around 1966 to 1967, and is limited to Uttar Pradesh, Punjab, and Madhya Pradesh. Its extension into Gujrat, Maharashtra, and the southern states is rather slow because of other well-established cash crops that cannot be replaced easily. The fifth Five Year Plan proposed to cover 430,000 ha under soybean. The statewide break-up of the area, as envisaged at the end of the plan by the Directorate of Soybean, Government of India, is 170, 155, 55, and 50 thousand hectares for Madhya Pradesh, Uttar Pradesh, Maharashtra, and Gujrat, respectively. Thus Madhya Pradesh alone would cultivate nearly 40 percent of the total acreage. With the prevalence of a very destructive yellow mosaic disease in Uttar Pradesh, the onus of the soybean expansion program will fall on Madhya Pradesh where the vast stretches of fallow land during the kharif season (July-October), used subsequently for wheat cultivation, can be profitably utilized to grow two crops instead of one. Soybean, with its inherent qualities of adaptability and yield, enjoys superiority over other pulses such as black gram (*Phaseolus mungo*) and green gram (*P. aureus*) and will superbly fit itself into the cropping pattern without upsetting the existing cultivation practices. Four factors govern successful soybean production: (a) viability and germination of seed; (b) *Rhizobium* treatment for seed in new areas; (c) weed control; and (d) pest and disease control. This paper deals with the insects of soybean.

The profuse foliage of soybean attracts a large number of insects, although the damage begins with the sowing of the seed and continues until harvest. Based on the nature of the damage, insects that affect soybean may be broadly classified as follows: (a) insects of seeds and germinating seedlings, (b) insects of stems, (c) insects of foliage, (d) insects of flowers and pods, and (e) insects of stored soybean grain.

Gangrade and workers have noted 85 species of insects from soybean fields over a 5-year period in Jabalpur.

Insects of Seeds and Germinating Seedlings

Crickets, ground beetles, and seed-maggots attack seeds in the soil, causing injury to moist and soft seeds. The seed-maggot severely threatens germination during the low temperature of the spring season when the seeds take an unduly long time for germination.

Seed-maggot *Hylemyia cilicrura* (Rond), known as seed-corn-maggot in the United States and Europe, attacks the seeds and germinating seedlings of soybean which cannot unfold their cotyledons and thus die prematurely. Gujrati et al. (3) observed that the number of maggots per 100 seedlings ranged from 9.25 to 14.75 on nine different varieties of soybean.

The eggs of the fly were laid near the seed and hatched in 4 to 5 days. Maggots were full-grown after feeding on the seed and seedlings in 11 to 14 days. The pupae were formed in the soil and emerged in 7 to 11 days (3).

The mean percentage of damage was the lowest (1.66 percent) in seeds treated with phorate (Thimet) 10 g (2 kg/ha). Other insecticidal treatments, disulfoton (Di-syston) 10 g (1 kg/ha), dimethoate (Rogor) 5 g (1 kg/ha), and BHC 10 percent dust (2.5 kg/ha), revealed 6.33, 8.33, and 5.33 percent damaged seeds, respectively, and were similar to control (untreated) with 8.66 percent.

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Insects of Stems

The stems of soybean are attacked by a stemfly *Melanagromyza phaseoli* (Tryon) and a girdle beetle, *Oberea brevis* (Swed.). The larvae of both these insects are sometimes present in a plant, but their regions of damage are distinctly separated and easily distinguishable. The stems infested by the stemfly are red internally, bearing zigzag galleries made by the maggots, whereas the stems containing the beetle grub are completely hollowed by its movements. The stemfly prefers to attack young plants in the unifoliate or first trifoliate leaf stage as against older plants generally selected by the beetle for oviposition, lest the plant die and destroy the grub. However, in both cases, one of the trifoliate leaves of the attacked plant displays symptoms of drooping and withering beyond the basal region, although the beetle-infested leaf additionally shows two parallel rings at the base of the drooping leaf.

Stemfly *M. phaseoli* is a very serious pest of soybean stems, infesting over 90 percent of plants from the unifoliate stage onwards. The plants remain susceptible to attack for about 4 to 5 weeks when the fly lays eggs below the epidermis of the leaves. The maggots bore into the stems to make galleries up to the root zone of the plant. Usually 1 to 3 pupae were found inside the stems and infested 8 to 40 cm of the length of the stems. At no time did any two maggots feed simultaneously. The drooping and withering leaf symptom was only sometimes displayed, or else the characteristic remained masked. About 1,700 varieties were screened but none exhibited any resistance to the stemfly.

Insecticides (active ingredient basis) such as disulfoton 5 g (1 kg/ha), dimethoate 5 g (1 kg/ha), phorate 10 g (2 kg/ha), trichlorofon (Dipterex) 5 g (1 kg/ha), temik (Aldicarb) 10 g (2 kg/ha), lindane 10 g (2 kg/ha), cytrolane 10 g (1.75 kg/ha), and carbofuran (Furadan) 3 g (1 kg/ha) were unable to completely reduce the stemfly, nor did they increase the yield significantly. However, lindane granules reduced the stemfly attack though not appreciably. Phorate and disulfoton were next best. Carbofuran, cytrolane, and lindane granules were similar to one another in effect.

Among the dusts, heptachlor 5 percent (1.25 kg/ha), carbaryl (Sevin) 10 percent (2.5 kg/ha), dieldrin 2.5 percent (2.5 kg/ha), BHC 10 percent (2.5 kg/ha), and lindane 1.3 percent (1 kg/ha), were used as soil insecticides before seeding. BHC and lindane gave the lowest percentage of stemfly-infested plants as observed by Kapoor et al. (10).

The foliar sprays of monocrotophos (Nuvacron) 40 e.c., endosulfan (Thiodan) 35 e.c., methyl demeton (Metasystox) 30 e.c., ethyl parathion (Folidole-E-605) 46.7 e.c., dimethoate 30 e.c., carbaryl wettable powder 50 percent, malathion 50 e.c., trichlorofon 80 percent soluble powder, and phosphamidon (Dimecron) 100 were used in spray concentrations of 0.04, 0.05, 0.03, 0.05, 0.03, 0.2, 0.05, 0.3, and 0.03 percent, respectively, at intervals of 10 days for seven times in the rabi season (December-April). Only monocrotophos, endosulfan, and dimethoate produced completely healthy crops and significantly increased the yield by 16 to 20 percent.

A combination of soil and foliar insecticides such as lindane granules or dust followed by 2 to 4 spray treatments of ethyl parathion/dimethoate/endosulfan/monocrotophos reduced the stemfly infestation but the increase in yield was not significant. However, a 16 to 20 percent increase was possible in the yield of treated plots over the untreated check.

The girdle beetle, *O. brevis*, is liable to become one of the potential pests of soybean. Kapoor et al. (7) reported that in 1969 it damaged 1.0 to 29.4 percent plants (average 13.4 percent) of soybean. In 1973 the range and mean percentage of infested plants (Table 1) was quite high in all varieties that were sown well before the outbreak of the monsoon rains on June 1, because the plants reached a vulnerable stage. The normal sowings of June 16 and July 1 were much less attacked, while those of July 16 and 31 received very minor infestation.

The adult beetle made two parallel rings on a stem, petiole, or the base of a trifoliate leaf before egg-laying (7). The larva, at maturity, girdled the stem from within at two locations ca 25 cm apart so that the plant broke off with the loss of pods. Healthy plants carried 41 percent more pods than the infested ones (Table 2) and the weight of pods and grain was more or less doubled (7).

Table 1. Percentage infestation of soybean by girdle beetle *Oberea brevis* in different dates of sowing.

Variety		Date of sowing				
		June 1	June 16	July 1	July 16	July 31
Bragg	range	8.50-52.0	7.0-9.5	0-5.0	3.0-3.0	3.5-5.5
	mean	32.8	8.2	2.5	3.0	4.5
Lee	range	8.0-28.0	1.5-7.0	2.0-10.0	2.0-3.0	0.5-2.5
	mean	19.0	4.2	4.2	2.5	1.5
Davis	range	16.0-34.0	0-4.0	0-10.0	2.5-3.5	2.0-3.6
	mean	27.6	2.0	4.1	3.0	2.8
UPSS-38	range	16.0-41.3	0.5-6.5	0-18.0	1.0-3.0	2.0-2.0
	mean	32.1	3.5	8.3	2.0	2.0
JS-2	range	21.5-94.0	2.5-6.5	0-3.5	1.5-3.0	0.6-1.0
	mean	59.1	4.9	1.5	2.2	0.8

Table 2. Number of pods and weight of pods and grain of 50 healthy soybean plants and 50 plants damaged by *Oberea brevis*.

Plant	Number of pods		Weight of pods(g)		Weight of grain	
	Total	Av/plant	Total	Av	Total	Av
Healthy	1,351	27.02	635.7	12.70	467.9	9.35
Damaged	958	19.16	340.0	6.80	238.0	4.76

The female girdle beetle laid 8 to 122 eggs which hatched in 4 to 8 days. The larvae were full-grown in 32 to 36 days in 1969 and 45 to 62 days in 1970 with a pupal period of 8 to 11 days. However, a great majority of the larvae remained in diapause from 241 to 322 days until the rains of the next year activated them, as observed by Gangrade et al. (2).

Endosulfan 35 e.c. in concentrations of 0.05 to 0.07 percent was significantly more effective than monocrotophos 0.04 percent and trichlorofon 80 s.p. (0.03 percent) in preventing the percentage increase of the beetle-infested plants.

Parasites *Dinarmus* sp. and *Citrina* sp. parasitized the full-grown larvae of the beetle in the stems. *Dinarmus* could be bred in the laboratory on the same host, as reported by Kapoor et al. (9).

Insects of Foliage

A vast spectrum of insects visits soybean for food and nutrition from the time the plants attain a few trifoliate leaves to maturity of the beans, including leaf-chewing, sap-feeding, rasping, and sucking types.

Among the leaf-chewing insects, both lepidopterous and coleopterous insects damage soybean, but the former predominate in numbers and injury. The regular insects of soybean leaves are classified as follows: (a) Open feeders, such as Bihar hairy caterpillar, *Diacrisia obliqua* Walker; linseed caterpillar, *Spodoptera (Laphygma) exigua* (Hubner); tobacco caterpillar, *Prodenia litura* F.; gram caterpillar, *Heliothis armigera* Hubner; brown striped semilooper, *Mocis undata* Fabricius; green semilooper, *Trichoplusia* sp.; looper, *Scopula remotata* Guen; leaf weevils, *Myllocerus* spp.; flea beetles, *Pugria kamaraensis* and *Longitarsus belgaumensis*; galerucid beetle, *Maduresia obscurasia* Jac.; and grasshoppers. (b) Leaf-folders, comprising the brown caterpillar, *Anarsia ephippias* Meyer; greasy green caterpillar, *Lamprosema indicata* Fab. and *L. diemmenalis*. (c) Leaf-miners, which are numerous, but of which *Stomopteryx subsecivella* Zeller is the most predominant.

The foliage feeders damaged 20.14 to 83.3 percent of soybean plants during the last 5 years of observation, and injured 8.86 to 55.42 percent of the leaves from such plants either partially or wholly. The flea beetles were present throughout the growing period and their population ranged from 19.58 to 24.0 per ten sweeps.

The larval population per 100 plants of soybean in respect to *H. armigera* was 0.26 to 1.42 in 1969, negligible in 1970 and 1971, and 3.5 to 8.25 in 1973. *S. (L.) exigua* larvae ranged between 0.26 and 2.75, showing no wide fluctations during 1969-1970. *Trichoplusia* larvae remained at 0.97 to 2.83 and *Lamprosema* between 2.85 and 14.47. The larvae of *Stomopteryx* built up gradually from a low of 0.7 to 7.0 in 1970 and 2.8 to 11.75 in 1972 to an average of 27.3 larvae per 100 plants in September 1973, when the insect appeared in outbreak form, as reported by Gujrati et al. (6). The leaf-injury and larval density always posed a problem in deciding on control measures.

Phytophagous insects and their parasites and predators have been studied in the laboratory. Gujrati et al. (6) have studied the biology of the leaf miner *S. subsecivella* (6), the brown striped semilooper *M. undata* (4), and larvae of looper *S. remotata* (5). The leaf-folder *L. indicata* has been observed by Kapoor et al. (8), and Singh and Gangrade (13) have studied the hairy caterpillar *D. obliqua* in some detail. Association of a pentatomid predator *Cantheconidia furcellata* with the tobacco caterpillar *S. (Prodenia) litura*, and a reduviid, *Rhinocoris fuscipes*, with the larvae of *D. obliqua* was observed.

To assess the threshold of economic damage by foliage insects of soybean, a study was conducted to determine the population level of larvae, amount of defoliation, and adverse effects on yield in terms of number of pods and weight of pods and grain (Table 3).

It is incorrect to say that the plants suffered in yield only when they were damaged in the pod development phase. Soybean plants suffered adversely from insect damage even in the preflowering stage. The destruction of 40 percent leaf area by the larvae of *Diacrisia* significantly reduced the yield. Ten larvae per meter of row length signified the beginning of the injury level which resulted in reduction of weight of grain by about 38.9 percent. Similarly, every rise in the larval density of *S. (L.) exigua* per meter of row length caused a significant increase in consumption of the leaf area, though yield reduction was not quite significant.

The podding stage of soybean plants was liable to suffer serious damage if it was attacked by the larvae. This was apparent when 10 larvae of *Heliothis* per meter of row length left practically no grain in the pods. Therefore control may have to be contemplated even at a lower density.

The sap-feeding insects observed on soybean include the whitefly, *Bemesia tabaci* Genn.; aphids *Rhopalociphum rufiabdominalis* and *Aphis craccivora*; several cicadellids (jassids) *Empoasca terminalis* Dist.; delphacid *Sogatella longifurcifera* Esa. and Ish.; capsid *Creotia pallidifer* Walker; and coreid *Riptortus linearis* Fab. The whiteflies were present throughout the year on soybean, whereas jassids and aphids were common in the spring.

Among the rasping and sucking insects, thrips such as *Caliothrips indicus* Bagnall, *Taeniothrips distalis* Karny, and *Thrips tabaci* attacked kharif soybean (July-October) in small numbers and were abundant on the spring crop (Table 4).

Control of the foliage feeders was rather easy. Two to four foliar spray treatments of monocrotophos 40 e.c., endosulfan 35 e.c., dimethoate 30 e.c., ethyl parathion 46.7 e.c., fenitrothion (Sumithion) 50 e.c., and methyl demeton 30 e.c. effectively controlled the foliage feeders in concentrations of 0.04, 0.075, 0.03, 0.02, 0.05, and 0.04 percent, respectively. Lindane and BHC dusts at 25 kg/ha were also effective in reducing foliage feeders. Carbaryl 50 percent w.p. in 0.2 percent concentration was one of the most effective insecticides against pests of soybean, but led to yield reduction on account of phytotoxicity.

Insects of Flowers and Pods

No insects have so far been recorded on the flowers of soybean, but pods were occasionally infested by the larvae of *Heliothis armigera* and a bug *Riptortus linearis* Fab. in Madhya Pradesh. The bug usually appeared when the pods were developing, as observed by Gangrade and Kapoor (1). A pentatomid, *Nezara viridula*, was noted sporadically in negligible numbers. In Japan an unidentified *Asphondylia* has been reported by Naito and Osaka (11), and *Grapholitha (Cydia) glycinivorella* Matsumara has been reported by Nishijima (12) as attacking the pods of soybean. At Jabalpur a coccid, *Nipaecoccus vestator* Maskell, caused damage to maturing pods in small patches.

Table 3. Effect of larval density on foliage, number of pods, weight of pods, and grain of soybean.

Larval density	Mean plant height (cm)	Percentage of leaf area	Mean pod number	Weight: Total pods(g)	Weight: Total grain(g)	Mean number of grains	Mean number of larvae surviving to pupation
			(i) *Diacrisia obliqua* (Preflowering stage)				
0	36.2	0	8.4	76.80	51.70	334.25	0
5	36.0	25.30	8.5	74.12	48.45	326.50	3.33
10	33.3	40.04	6.7	56.80	37.22	251.75	5.70
15	30.2	64.29	5.3	36.75	23.95	181.50	8.49
20	28.5	82.18	4.6	30.60	20.05	164.00	11.74
S E	2.02	0.63	0.90	10.90	6.87	42.00	0.66
C_D 5%	--	1.93	2.76	33.48	20.98	129.04	2.02
			(ii) *Laphygma exigua* (Preflowering stage)				
0	40.5	0	7.9	78.30	53.46	318.25	0
5	38.9	14.26	7.7	72.09	51.77	303.75	2.80
10	36.8	24.61	7.2	68.95	47.32	290.50	5.50
20	35.5	26.08	6.9	62.40	42.77	272.75	9.90
40	35.2	32.56	7.7	67.78	47.08	279.75	18.95
S E	6.60	0.03	0.42	2.45	2.11	14.87	0.02
C_D 5%	--	0.09	--	7.52	6.48	--	0.05
			(iii) *Heliothis armigera* (Pod development stage)				
0	33.9	0	3.8	--	12.69	--	0
5	33.7	76.34	3.9	--	10.87	--	2.88
10	32.3	42.46	2.5	--	1.08	--	5.99
20	33.3	48.18	3.2	--	1.31	--	9.33
30	34.2	32.45	2.6	--	0	--	14.22
40	33.8	19.54	2.1	--	0.04	--	18.88
S E	1.23	0.99	0.34	--	1.60	--	0.02
C_D 5%	--	3.11	1.04	--	5.02	--	0.06

Table 4. Mean population of jassids, aphids, whitefly, and thrips in different varieties of soybean.

	Method of collection							
	Jassids		Aphids		Whitefly		Thrips	
Year and season	Sweep	Shake	Sweep	Shake	Sweep	Shake	Sweep	Shake
1970 (Dec.-April)	75.26	46.14	16.99	12.97	63.19	27.0	66.4	163.3
1971 (July-Oct.)	22.58	--	--	--	55.95	--	68.96	--
1972 (Jan.-April)	85.75	7.47	56.16	71.78	16.71	26.40	208.83	588.9

Insects of Stored Soybean Grain

Grain exposed to damp, moist conditions was prone to damage by the larvae of *Ephestia (Cadra) cautella*, but well-protected grain stored in gunny bags and polythene sacks and containing less than 12 percent moisture remained healthy and uninfested. Under the same conditions, however, the pulse beetle *Bruchus chinensis* appeared to damage soybean grain.

REFERENCES

1. Gangrade, G.A., and K.N. Kapoor. 1973. A coreid bug on soybean. FAO Plant Prot. Bull. 21(5):116.

2. Gangrade, G.A., K.N. Kapoor, and J.P. Gujrati. 1971. Biology, behavior, diapause, and control of *Oberea brevis* Swed. (Col:Cerambycidae-Lamiinae) on soybean. Entomologist 104:260-264.

3. Gujrati, J.P., K.N. Kapoor, and G.A. Gangrade. 1971. Incidence and control of seed-corn-maggot *Hylemyia cilicrura* Rond. on soybean. Indian J. Ent. 2:366-368.

4. Gujrati, J.P., K.N. Kapoor, and G.A. Gangrade. 1971. *Mocis undata* F. (Lepidoptera: Noctuidae)--a pest of soybean (*Glycine max* L. Merrill) in Madhya Pradesh. Entomologist 104:33-36.

5. Gujrati, J.P., K.N. Kapoor, and G.A. Gangrade. 1973. Biology of *Scopula remotata* Guen. (Lepidoptera:Geometridae) on soybean. J. Nehru K.V.V. Res. J. 7(3):162-165.

6. Gujrati, J.P., K.N. Kapoor, and G.A. Gangrade. 1973. Biology of soybean leaf miner *Stomopteryx subsecivella* (Lepidoptera:Gelechiidae). Entomologist 106:187-191.

7. Kapoor, K.N., G.A. Gangrade, and J.P. Gujrati. 1971. Note on the effect of infestation by *Oberea brevis* Swed. (Coleoptera:Lamiidae) on pods and yield of soybean (*Glycine max* L. Merrill). Indian J. Agr. Sci. 41:272-273.

8. Kapoor, K.N., J.P. Gujrati, and G.A. Gangrade. 1972. Bionomics of *Lamprosema indicata* Fabricius (Lepidoptera:Pyralididae)--a pest of soybean in Madhya Pradesh. Indian J. Ent. 34:102-105.

9. Kapoor, K.N., J.P. Gujrati, and G.A. Gangrade. 1972. Parasites of *Oberea brevis* (Coleoptera:Lamiidae). Ann. Ent. Soc. Amer. 65:755.

10. Kapoor, K.N., J.P. Gujrati, and G.A. Gangrade. 1973. Chemical control of soybean stemfly, *Melanagromyza phaseoli* Tryon. Pesticides 7:31-32.

11. Naito, A., and K. Osaka. 1960. Occurrence of soybean pod gallmidge and its hymenopterous parasites in Kanto district and notes on parasites. Jap. J. Appl. Ent. Zool. 3(2):91-96.

12. Nishijima, Y. 1959. Occurrence of embryoless seeds in soybean varieties in relation to feeding of soybean pod borer, *Grapholitha glycinivorella* Matsumara. Jap. J. Appl. Ent. Zool. 3(3):183-189.

13. Singh, O.P., and G.A. Gangrade. 1974. Biology of *Diacrisia obliqua* Walker (Lepidoptera: Arctiidae) on soybean and effect of loss of chlorophyll on pod and grain. J. Nehru K.V.V. Res. J. (in press).

Weeds Associated with Soybeans and Their Control

V.M. Bhan

Soybean is grown for its protein and oil all over the world. It is much more important as a source of protein, especially in a country where the population in general is vegetarian or high-cost animal protein cannot be consumed by the average population. In India, total acreage under soybean is very small; however, area is increasing progressively with the availability of seed material and technical know-how concerning its cultivation and utilization in the commonly prepared dishes of the country.

Soybean was introduced approximately a decade ago for extensive research and development. It has found wide adaptability in subtropical and temperate climatic conditions. Main planting season in north and central India starts with the onset of rains from June to early November. The climate remains warm and humid. The crop produces prolific growth and maximum yields are obtained during this season. Soybean has also been found to grow during the spring season (February to June). One must have an assured supply of irrigation to get a crop during this part of the year. High cost of irrigation prohibits its cultivation. Soybean-wheat is the rotation commonly followed by the farmers.

Impact of Weeds

Presence of weeds in soybean fields reduces crop yields from 40 to 50 percent depending on the intensity of weed infestation. Annual weeds, especially of the *Gramineae* family, cause maximum damage. Important annual grasses include *Echinochloa colonum* L. Beauv., *E. crusgalli* L., *Elusine indica, Setaria glauca* L. Beauv., *Dactyloctenium aegyptiacum* L. Richter, *Digitaria sarguinalis* L. Scop., and *Cyperus iria* L. Among broad-leaved weeds *Amaranthus viridis, Cleome viscosa* Linn., *Euphorbia hirta, Solanum nigrum, Phyllanthus niruri* L., *Celosia argentea, Physallis minima, Corchorus aecutangulus,* and *Commelina benghalensis* are prominent ones. In addition, two perennial weeds that infest soybean fields are *Cyperus rotundus* and *Cynodon dactylon* L. Pers.

These annual weeds emerge with the terminating crop seedlings and grow along with them. This causes severe crop-weed competition during the early stages of crop growth, thereby reducing the crop yields substantially. At Pantnagar in 1967-69 (8) significant reductions were recorded when weeds were allowed to compete for more than 30 to 35 days after sowing (Table 1). Grasses and sedges constituted 76 percent of the total weed population. The reappearance and growth of weeds in plots where weeds were removed after 30, 45, and 60 days of competition with the crop plants decreased with advancement in time of weed removal. Weeds that emerged after 30 days of planting did not influence soybean yield. Decrease in yield was mainly caused by competition from weeds that stayed in the plots for longer than 30 days. Knake and Slife (11) also found that foxtail competition caused 27 percent reduction in crop yield when both were planted at the same time.

To avoid competition during early stages of crop growth it is necessary to keep fields free of weeds. Experiments conducted at Pantnagar in 1968-70 (8) on the need for weed-free maintenance in soybean reveal that maximum yields were obtained when fields were kept weed-free for 15 and 30 days after sowing was not significant. Knake and Slife (11) have reported 27 percent reduction in soybean yield when *Setaria faverii* was planted at the same time the soybean crop was planted. The same weed, seeded three weeks later, did not cause yield reductions. Aleman and Nieto (1) in corn, and Hill and Sangleman (10) in groundnut, reported 60 and 40 days' requirement, respectively, for weed-free conditions to produce maximum yield. These observations indicate competition by weeds in most of the crops at early stages of growth. In Brazil it has been reported that there is no significant

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difference in grain yield in plots kept weed-free for the first 45 days compared with plots which were maintained weed-free for the whole season. Vega (14) in the Philippines also obtained optimum yield of soybean when kept weed-free for the first 40 days after sowing.

Table 1. Effect of time of weed removal on the yield of soybean.

Treatment	Grain yield 1967	1968 (q/ha)	1969	Mean
Weed-free check	26.2	31.9	29.2	29.1
Weed removal time				
15 days after sowing	24.4	30.1	31.6	28.7
30 days after sowing	13.8	30.2	27.8	23.9
45 days after sowing	3.2	28.0	25.0	18.7
60 days after sowing	2.8	17.4	a/	10.1
At harvest (weedy check)	2.1	16.2	19.8	12.7
LSD 5%	5.3	3.5	3.9	--

[a/] Not treated in 1969.

Table 2. Effect of period of weed-free maintenance on yield of soybean.

Period of weed-free maintenance (days after sowing)	Grain yield (q/ha) 1968	1969	1970
0 (weedy control)	3.6	20.8	13.1
15	26.1	27.4	21.0
30	33.7	31.9	21.3
45	34.5	29.9	21.6
60	32.6	39.2	21.8
Weed-free maintenance up to harvest	34.0	31.0	22.6
SE	3.1	2.9	1.0
C_D 5%	10.3	9.6	3.3

It would be of interest to study the emergence of weeds and their growth when emerged at different stages of crop growth. It has been observed (Tables 3 and 4) that emergence and dry matter produced by total weeds was markedly decreased after the crop was kept weed-free up to 30 days of sowing. Seventy-five to eighty percent of the weeds re-emerged in plots kept weed-free up to 15 days of sowing, and 20 to 30 percent re-emerged when kept weed-free up to 30 days after sowing. There was no weed emergence in plots where a weed-free period of 60 days and longer was maintained.

The preceding study indicates that, if chemical means are to be adopted to control weeds, the herbicide should have a residual effect lasting at least to the end of this critical period. In fact, no herbicide needs to persist longer. These data are important for two reasons: First, this may act as a parameter in developing new herbicides, and second, in areas where soybean is followed immediately by a winter-season crop, especially wheat, the residual activity of a herbicide applied to the soybean crop must end for successful production of wheat. After 30 days of weed-free maintenance or termination of the critical phase, soybean generally spreads enough canopy to compete successfully with weeds, thus controlling them effectively.

Table 3. Effect of period of weed-free maintenance on population of different species of weeds.

Weed species	*Cyperus iria*			*E. colonum*			*C. benghalensis*			Other grassy weed			Other broad-leaved			Total weed species		
Days after sowing	30	45	60	30	45	60	30	45	60	30	45	60	30	45	60	30	45	60
Period of weed-free maintenance (days after sowing)	(plants per square meter)																	
	1968																	
0[a/]	100	86	81	55	50	47	30	43	45	35	17	20	36	16	15	256	212	208
15	66	52	32	45	38	23	35	27	24	18	32	39	16	16	39	180	165	157
30	-	8	7	-	5	6	-	3	7	-	7	11	-	5	14	-	29	45
45	-	-	4	-	-	3	-	-	-	-	-	4	-	-	4	-	-	17
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WF[b/]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1969																	
0[a/]	98	80	55	65	52	28	38	26	21	11	12	9	11	10	11	226	180	124
15	86	75	47	59	51	24	29	24	23	12	6	14	9	4	12	195	160	100
30	-	3	14	-	4	9	-	2	9	-	3	3	-	3	3	-	15	38
45	-	-	15	-	-	11	-	-	7	-	-	4	-	-	3	-	-	40
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WF[b/]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970																	
0[a/]	92	89	85	52	49	37	28	22	21	39	31	32	37	28	19	248	219	194
15	84	66	62	48	42	32	22	19	20	26	21	24	22	18	22	202	166	160
30	-	8	10	-	7	9	-	4	7	-	6	10	-	8	13	-	33	39
45	-	-	6	-	-	6	-	-	6	-	-	3	-	-	7	-	-	28
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WF[b/]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

a/ Weedy control.

b/ WF = weed-free maintenance up to harvest.

Table 4. Effect of period of weed-free maintenance on dry-matter production of weeds and crop plants.

Period of weed-free maintenance (days after sowing)	Dry-matter production by weeds (g/m_2) (days after sowing)									Dry-matter production by crop plants (g/plant) (days after sowing)								
	30	45	60	30	45	60	30	45	60	30	45	60	30	45	60	30	45	60
	1968			1969			1970			1968			1969			1970		
0[a/]	148	378	695	143	490	572	138	212	354	4.3	9.8	13.2	5.6	9.6	15.7	6.5	9.5	14.4
15	95	290	689	79	165	274	129	185	260	5.2	11.0	13.7	6.1	10.7	19.1	11.7	14.4	17.8
30	-	62	381	-	45	116	-	88	156	5.8	11.1	14.6	7.2	12.5	19.1	15.4	19.4	22.3
45	-	-	116	-	-	98	-	-	123	6.4	11.3	15.3	6.6	11.3	19.5	16.2	19.8	23.5
60	-	-	-	-	-	-	-	-	-	6.9	11.7	20.0	6.7	12.4	22.8	17.5	18.6	22.9
WF[b/]	-	-	-	-	-	-	-	-	-	7.2	13.2	20.0	6.9	13.2	19.4	18.5	24.3	24.4

a/ Weedy control.

b/ WF = weed-free maintenance up to harvest.

Both mechanical and chemical methods, singly or in combination, are practiced to combat weeds in soybean fields.

Mechanical Methods of Weed Control

Mechanical methods are widely used in India and other developing countries to keep soybean fields free of weeds. These methods include manual removal using khurpi (chisel-like hand tools), spades, hand hoes, and the like. Animal- or tractor-drawn intercultivators are also used. Size of hoe in the intercultivating equipment varies with soil type and moisture conditions prevailing in the field.

Manual removal of weeds using khurpi accomplishes the job effectively. Two weedings at 15 and 45 days after sowing keeps the field clean throughout the cropping period. Each weeding requires 25 to 35 man-days per hectare. Each man unit is 8 h/day. Use of spades and hoes have been found equally effective for weeding (Table 5). However, each hoeing required about 20 to 25 man-days per hectare. The only problem often faced in hoeing is the presence of weeds between the plants within a row, which cannot be removed by hoeing. A similar problem is found when the animal- or tractor-powered intercultivator is used. Mechanical weeding techniques, especially hoeing and use of intercultivators, are difficult to practice after 35 to 40 days of crop growth because of the dense canopy that develops after that period. This impedes movement and crop plants are often damaged.

As stated earlier, mechanical methods are effective but costly and time-consuming. Availability of manpower at the right time for weeding is difficult and may delay the operation. In a country such as India, continuous rains during the growing season do not permit use of mechanical methods. Weeds are often removed so late that they have already done their damage. The use of manpower is costly, too, especially during the critical stages when weeding is necessary. Where the farm area is large, manual removal of weeds is too time-consuming to cover the area at the right time.

These problems indicate the importance of using herbicides for weed control in soybean fields and number of scientists in subtropical and tropical regions have worked on developing such methods.

Table 5. Effect of mechanical and chemical weeding methods on yield of soybean (1969).

Treatment	Yield (q/ha)
Alachlor (3 kg/ha)	34.2
Hoeing (two times)	35.4
Weed-free check[a]	33.7
Weedy check	20.7
SE	2.2
C_D	6.3

a/ Weed-free check had four manual weedings at 15-day intervals up to sixtieth day of sowing.

Use of Herbicides

A number of herbicides have been tested to achieve the desired weed control without damage to the soybean crop. Trifluralin and EPTC (alone and in combination), Alachlor, Vernolate, Linuron, and Amiben were tested along with hoeing, weed-free, and weedy controls at Pantnagar (8) in 1968-69 (Table 6). Alachlor at 3 kg, Vernolate at 6 kg and Trifluralin at 1 kg (active ingredient) per hectare, respectively, gave successful control of weeds and higher yields of soybean. Amiben did not control weeds, presumably because heavy rains may have leached the herbicide into the subsoil, leaving no effect on the surface. Linuron at 2.25 and 3 kg/ha revealed toxic symptoms but plants recovered later. EPTC at 4 and 6 kg/ha produced stunting at the time of seedling emergence.

Table 6. Effect of various herbicides on yield of soybean.

Herbicide	Rate of application (kg ai/ha)[a]	Yield (q/ha) 1968	1969
Trifluralin	0.5	17.2	26.9
Trifluralin	1.0	25.9	25.8
Trifluralin	1.5	25.0	29.8
EPTC	2.0	21.9	23.7
EPTC	4.0	15.9	22.9
EPTC	6.0	26.7	24.7
Alachlor	1.0	19.7	23.0
Alachlor	2.0	17.2	27.2
Alachlor	3.0	24.6	34.2
Vernolate	2.0	18.6	
Vernolate	4.0	24.3	29.8
Vernolate	6.0	25.8	32.1
Linuron	1.5	b/	21.1
Linuron	2.25	b/	24.0
Linuron	3.0	b/	26.4
Amiben	2.0	b/	26.1
Amiben	3.0	b/	26.2
Amiben	4.0	b/	26.1
EPTC + Trifluralin	2+0.5	b/	21.4
EPTC + Trifluralin	4+1.0	b/	28.6
EPTC + Trifluralin	6+1.5	b/	26.2
Hoeing		b/	35.4
Weed-free		25.4	33.7
Weedy		20.1	20.7
SE		2.3	2.2
C_D 5%		6.4	6.3

a/ Active ingredients=ai.

b/ Not treated.

Alachlor, Prometryne, Chloroxuron, Nitrofen, Rowmate, BAS-2900, USB-3584, MON-097, Terbutryne, and Oxadiazon were tested along with weed-free and weedy controls (Table 7) at Pantnagar (8). Alachlor, Prometryne, Nitrofen, MON-097, and Oxadiazon proved effective at some concentrations. Terbutryne proved extremely toxic.

Working at Jabalpur under central Indian conditions, Bajpai et al. (3) found that EPTC at 6 kg/ha, incorporated before sowing, and Alachlor at 1 kg/ha applied pre-emergence, yielded comparable to 6 hand weedings. In Argentina, Hemsy et al. (9) found that 30 cm row spacing along with Alachlor or Chloramiben gave best results.

Wax (15) obtained highest soybean yields by using Trifluralin at the time of seed-bed preparation, followed by Linuron applied at planting. Paraquat was not effective. It has been found that on loamy sand the combination of Vernolate at 2.24 kg/ha presowing and Chloroxuron at 1.12 kg/ha + 0.25 wetting agent early postemergence gave satisfactory control of *Cyperus esculentus* and 99 to 100 percent control of *Xanthium pensylvenicum*.

The use of postemergence nonselective herbicides has also been tried. Buchanan et al. (7) have reported successful use of Paraquat postemergence spray when used at 0.5 kg/ha. Higher concentrations proved phytotoxic to the crop plants.

BAS-2900 H, Sencor, CRD 69-6292, Preforon, Pyrazon, Oxadiazon, and Alachlor were tested (8) for weed control at Pantnagar (Table 8). Sencor at 0.5 kg, CRD 69-6292 at 3 kg, and Oxadiazon at 1 kg per hectare, respectively, proved effective and yields were at par with those obtained under weed-free treatments.

Table 7. Effect of herbicides on yield of crop and control of weeds.

Herbicide	Rate of application (kg ai/ha)[a]	Yield (q/ha) 1970	Yield (q/ha) 1971	Weed control (%) 1970	Weed control (%) 1971
Alachlor	1.0	23.7	--	53	--
Alachlor	2.0	26.1	21.0	83	80
Alachlor	3.0	24.9	--	89	--
Prometryne	1.0	24.7	--	81	--
Prometryne	2.0	4.9	--	88	--
Prometryne	3.0	1.4	--	92	--
Chloroxuron	1.0	26.3	15.1	68	68
Chloroxuron	2.0	25.2	17.4	73	78
Chloroxuron	3.0	23.9	16.1	73	85
Nitrofen	1.0	24.6	22.6	72	71
Nitrofen	2.0	26.3	23.5	80	75
Nitrofen	3.0	27.8	20.9	81	80
Rowmate	2.0	--	17.7	--	34
Rowmate	3.0	--	16.4	--	23
Rowmate	4.0	--	15.9	--	20
BAS-2900 H	2.0	--	22.6	--	56
BAS-2900 H	3.0	--	21.6	--	51
BAS-2900 H	6.0	--	19.5	--	66
USB-3584	0.25	--	20.4	--	54
USB-3584	0.50	--	14.6	--	40
USB-3584	1.0	--	13.3	--	35
MON-097	1.0	--	24.4	--	95
MON-097	2.0	--	29.7	--	86
MON-097	3.0	--	21.7	--	93
Terbutryne	1.0	--	17.3	--	92
Terbutryne	2.0	--	7.5	--	87
Terbutryne	3.0	--	4.4	--	100
Oxadiazon	0.5	--	28.4	--	94
Oxadiazon	1.0	--	11.5	--	95
Oxadiazon	1.5	--	7.5	--	95
Weed-free		26.8	25.2	100	100
Weedy		19.5	10.8	0.0	0.0
SE		1.54	2.82	--	--
C_D 5%		4.32	7.80	--	--

[a] Active ingredients = ai.

Among the new herbicides tested in 1973 (Table 9), C-288, C-19490, Basalin, and Basagran were compared with weedy and weed-free controls. Basalin at 2 kg/ha proved effective.

Use of Dinoseb at 1.25 lb/a followed by 0.2 lb/a of 2,4-DB gave complete control of cocklebur in soybean as reported by Talbert et al. (13). Anderson et al. (2) reported excellent control of weeds with 0.84 kg/ha of Bentazon. Under flooding conditions Bentazon caused injury, thereby reducing crop yield to the level of the weedy control.

Table 8. Effect of herbicides on weed control and soybean yield (1972).

Herbicide	Rate of application (kg ai/ha)[a]	Grain yield (q/ha)	No. of plants per 10 m^2	Percentage weed control (70 DAS)[b]
BAS-2900 H	2.0	30.7	187	77
BAS-2900 H	3.0	28.4	195	77
BAS-2900 H	4.0	29.6	189	90
Sencor	0.25	34.3	177	97
Sencor	0.50	36.1	163	97
Sencor	1.00	32.8	169	100
CRD 69-6292	1.0	26.8	247	67
CRD 69-6292	2.0	28.1	174	80
CRD 69-6292	3.0	36.9	158	87
Preferon	0.50	22.1	168	43
Preferon	1.00	29.5	167	67
Preferon	1.50	32.0	175	67
Pyrazon	2.0	7.9	80	23
Pyrazon	4.0	2.6	64	47
Pyrazon	6.0	0.4	4	47
Oxadiazon	0.50	30.3	148	83
Oxadiazon	1.00	37.9	164	83
Oxadiazon	1.50	37.9	163	80
Alachlor	2.0	33.4	169	93
Weed-free	--	38.9	184	100
Weedy	--	15.1	121	0
SE		3.55	24.70	
C_D 5%				

a/ Active ingredients = ai.

b/ DAS = days after spraying.

Where *Sorghum halepanse* (Johnson grass) is the problem, McWhorter (12) reported effective control without soybean injury using Trifluralin or Nitralin herbicides. Johnson grass was controlled effectively by using 1.68 to 3.36 kg/ha Trifluralin or Nitralin. Herbicides were incorporated immediately after application.

In subtropical regions, during the rainy season the rain storms are very heavy. This often causes leaching of herbicides applied on the surface or washing away of the surface soil itself. In either case, herbicides applied preemergence have been found to give reduced weed control. Bhan et al. (5) reported significantly higher yield when Alachor was applied as preplant incorporation than when used as preemergence spray, especially at 1 and 2 kg/ha (Table 10).

New Herbicides

Basagran, it is still an experimental compound. Soybean tolerance to Basagran is good when it is applied as a postemergence spray. Weed control is generally excellent.

Tolban, known as CGA 10832, is being tested. It is another dinitroaniline preplant product like Treflan.

Lexone, known as metribuzin, is similar to Sencor, widely used as combinations. It is most effective on broad-leaved weeds. Injury occurs at levels above 1 kg/ha.

Surflan is similar to Treflan but is applied as a preemergence spray rather than preplanting. It is less volatile than Treflan and is recommended for soils having less than 3 percent organic matter. It is to be used as mixed herbicide.

Basaline, an experimental product, is a dinitroaniline incorporated preplanting.

Lasso II, basically improved Lasso, gives better initial weed control. It is effective under a wide range of soil moisture conditions.

Lasso Sencer is best suited for heavier soils where grasses and tough broad-leaved weeds are a problem.

Lasso-Maloran and Lasso-Bromex are suited for light to medium soils for control of grasses and broad-leaved weeds.

Table 9. Preliminary evaluation trial of herbicides applied to soybean, 1973.

Treatment	Rate of application (kg ai/ha)[a/]	Grain yield (q/ha)	Dry matter of weeds per m^2 at 75 DAS[b/]
C-288	0.5	15.22	165.33
C-288	1.0	20.57	128.00
C-288	2.0	18.75	218.66
C-19490	0.5	15.24	122.66
C-19490	1.0	17.16	202.66
C-19490	1.5	20.41	293.33
Basalin	0.5	15.94	245.33
Basalin	1.0	21.73	192.00
Basalin	2.0	23.89	96.00
Basagran	0.5	13.56	154.66
Basagran	1.0	19.14	250.66
Basagran	2.0	15.22	165.33
Lasso	2.0	21.20	134.66
Weed-free		26.93	0.00
Weedy		19.03	254.66
SE		1.92	41.60
C_D 5%		5.81	126.00

a/ Active ingredients = ai.
b/ DAS = days after spraying.

Table 10. Effect of varying method of application of Alachlor in soybean, 1971.

Herbicide	Rate of application (kg ai/ha)[a/]	Method of application	Grain yield (q/ha)	No. of plants per 10 m^2	Percentage weed control (70 DAS)[b/]
Alachlor	1	Preplanting	24.4	173	90
Alachlor	1	Preemergence	12.6	162	50
Alachlor	1	Postemergence	6.3	94	0
Alachlor	2	Preplanting	29.6	162	100
Alachlor	2	Preemergence	17.4	213	67
Alachlor	2	Postemergence	6.3	212	0
Alachlor	3	Preplanting	27.4	196	100
Alachlor	3	Preemergence	22.9	162	70
Alachlor	3	Postemergence	8.1	109	13
Weed-free			26.3	218	100
Weedy			14.4	212	0
SE			1.02	22	
C_D 5%			3.08	--	

a/ Active ingredients = ai.
b/ DAS = days after spraying.

REFERENCES

1. Aleman, F., and J. Nieto. 1968. The critical periods of competition between weeds and corn in high valleys of Toluca, Mexico. Weed Sci. Soc. of Amer. Abstr:150.
2. Anderson, R.N., W.E. Lueschan, D.D. Warner, and W.W. Nelson. 1974. Controlling broad-leaved weeds in soybeans with bentazon in Minnesota. Weed Sci. 22:136.
3. Bajpai, R.P., A.B.S. Verma, and C.R. Bisen. 1972. A note on the evaluation of cultural and chemical methods of weed control in soybeans. Ind. J. Weed Sci. 4:120.
4. Bhan, V.M., M. Singh, and R.A. Maurya. 1972. Studies on the chemical control of weeds in soybean. Ind. J. Weed Sci. 4:16.
5. Bhan, V.M., M. Singh, and R.A. Maurya. 1974. Effect of time and level of Alachlor application on weed control and yield of soybean. Ind. J. Agron. (in press).
6. Bhan, V.M., M. Singh, and R.A. Maurya. 1974. Performance of some new herbicides on weed control in soybean. Ind. J. Weed Sci. (in press).
7. Buchanan, G.A., D.L. Thurlow, and H.T. Roger. 1971. Soybean production: weeds and their control. Auburn University Agr. Exp. Sta. Bull. 413.
8. G.B. Pant University of Agr. and Tech. Annual Report, Experiment Station, 1968-69, 1969-70, 1970-71, 1971-72, 1972-73.
9. Hemsy, V., M. Rodriguez, R. Inigo, and J.A. Cajal. 1971. Control of weeds in soybeans. Studies on the interaction of herbicides and between row spacing. Weed Abstr. 23:31.
10. Hill, L.V., and P.W. Santleman. 1969. Competitive effects of annual weeds on Spanish peanuts. Weed Sci. 17:1.
11. Knake, E.L., and F.W. Slife. 1965. Giant foxtail seeded at various times in corn and soybeans. Weeds 13:331.
12. McWhorter, C.G. 1974. Johnson grass control in soybeans with trifluralin and nitralin. Weed Sci. 22:111.
13. Talbert, R.E., R.E. Frans, and L.R. Oliver. 1973. Dinoseb in a herbicide program for controlling cocklebur in soybeans. Ark. Farm Res. 22(1):5.
14. Vega, M.R. 1968. Weed control in soybeans at the University of Philippines. Page 65 in Proc. Philippines Sci. Conf.
15. Wax, L.M. 1972. Weed control for close drilled soybeans. Weed Sci. 20:16.

DISCUSSION

R.K. JANA: Under high rainfall and temperature conditions, biodegrading is faster; as a result, residue effect is very limited. Therefore, grasping of pollution. When herbicide is applied, is a relative one depending on agro-climatic factors.

W. PLARRE: I agree to your opinion that weed operation should be done during the first 30 to 40 days after planting. But I do not agree that we should apply so many herbicides. At IITA located in the humid tropics, we also have great problems with weeds. But we have shown that it is possible to carry out all the weeding operation without any application of chemicals. This can be done by using hoes, rotary hoes, and tractors to remove the weeds mechanically; however, a good stand of the soybeans after emergence is a necessary condition.

We should not forget we already are applying so many chemicals against pests and disease. We do not have enough information as to what happens with all the residues, and we should be careful of environmental pollution. I think this responsibility belongs to all of us. There is another point which should be mentioned. We select resistant genotypes in the weeds by applying so many chemicals. For instance, we know that in barley many varieties are resistant to DDT and others are killed by this pesticide. This also can happen in using herbicides.

Soybean Processing, Products, Characteristics, and Uses

D.W. Johnson

Those who have been concerned about the relationship between population growth in the world and food supply, have recognized that conventional protein foods such as dairy products, meat, and eggs cannot be relied upon to supply those demands in the world picture. Even in the more affluent nations, such as the United States, where we have had overall adequate protein supplies, and will have good supplies for the foreseeable future, economics tends to dictate changes in ingredients that are used in processed foods.

There was a time when U.S. agricultural production was at such a level that we had large surpluses, so we were able to supply large quantities of food and feed grains to other areas of the world without difficulty. However, the situation has rapidly changed and for practical purposes we have no surpluses and are not likely to have any real surpluses ever again.

The most important U.S. farm crop of the last 30 or 40 years, which is responsible for the livestock economy we enjoy in the United States, is the soybean. Table 1 shows that, since 1924, the U.S. production of soybeans has increased from 135,000 metric tons to over 42,000,000 metric tons in 1973. The yield average in 1924 was 0.74 metric ton per hectare and in 1973 averaged 1.87 metric tons per hectare. The 1973 average yield in the state of Illinois, with harvest from over 3.7 million hectares, was 2.2 metric tons per hectare, and in the State of Iowa, with harvest from over 3.2 million hectares, was almost 2.3 metric tons per hectare.

The big use for protein in the form of soybean meal is for animal feed purposes but increasing quantities of the soy protein-containing portion of the soybean are being used in various ways as human food. New technology and economics will see a sharp rise in the increase in soy protein-containing products for human food. Table 2 presents figures for protein concentrate production and feed use of these concentrates in the United States for years 1962-1963 and 1972-1973. The figures for feed use represent domestic production plus imports, minus estimated food, industrial, and nonfeed uses. This table indicates that, of the protein concentrates used in animal feed, soybean meal makes up over 62 percent of the total. But, on a protein basis, the percentage would be considerably higher. Based on 1972 figures, the consumption of soybean meal in the United States on a percentage basis was approximately as follows: poultry, 42 percent; hogs, 19 percent; beef cattle, 13 percent; dairy cattle, 11 percent; and other uses, 15 percent.

Practically everywhere in the world there is a great desire for meat products. With increasing affluence in some areas of the world, the demand per capita for meat products is increasing, and so is the price. With the projected population increase, it does not appear possible for the world to supply sufficient protein in the form of animal products to satisfy nutritional needs and demands.

Table 3 shows the red meat consumption per capita in 1971 for selected areas of the world. It seems unlikely, even if everyone could afford to purchase meat products, that it will be at all possible to bring the level of red meat consumption per capita up to the levels of Canada, the United States, some areas of Oceania, and South America.

Table 4 gives figures on the number of people who could theoretically be fed for one day by protein from various sources based on production from one hectare of land in one year. It is obvious from these figures that the amount of land needed to produce protein as animal protein is much less efficient than vegetable protein. Further, when one considers that the cereal grains are relatively low in protein and relatively poor in protein quality, it is obvious that the growing of soybeans gives the best land use for protein production.

D.W. JOHNSON: President, Food Ingredients, Incorporated, 1150 Willis Ave., Wheeling, IL 60090, USA.

Table 1. Production and yield of soybeans, United States, selected years.

Year	Production (1,000 mt)	Yield (mt/ha)	Yield Range
1924	135	0.740	.370-1.009
1944	5,229	1.264	
1964	19,076	1.533	
1973	42,640	1.870	1.278-2.287

Source: Soybean Digest Blue Book. 1974. American Soybean Assn., P.O. Box 158, Hudson, IA 50643, USA.

Table 2. Protein concentrate production, United States.

Protein concentrate	1962-1963 Production (1,000 mt)	1962-1963 Feed use[a] (1,000 mt)	1972-1973 Production (1,000 mt)	1972-1973 Feed use[a] (1,000 mt)
Soybean meal	9,624	8,290	15,158	10,861
Cottonseed meal	2,477	2,446	2,057	2,018
Linseed meal	363	297	327	192
Peanut meal	72	72	164	163
Copra meal	84	84	91	91
Gluten feed and meal	1,241	1,241	1,573	1,573
Tankage and meat scraps	1,758	1,760	1,571	1,578
Fish meal	271	669	338	442
Dried milk products	194	194	299	299
Other milk products	519	519	317	317
Total	16,603	15,572	21,895	17,534

a/ Domestic production plus imports, minus estimated food, industrial, and nonfeed uses.

Source: *See* Table 1.

Table 3. Red meat consumption per capita, selected countries, 1971.

Country	Total red meat[a/] (lb)	Beef and veal (lb)	Pork (lb)	Mutton, lamb and goat (lb)
United States	87.3	52.7	33.2	1.4
Canada	74.6	42.3	30.5	1.8
European community	55.5	25.0	28.2	1.4
Eastern Europe				
Bulgaria	31.8	10.9	11.8	9.1
Czechoslovakia	53.7	19.1	34.1	0.5
Hungary	50.1	9.1	40.5	0.5
Poland	40.9	15.5	24.1	0.9
Yugoslavia	35.0	11.8	20.5	2.7
Russia	40.5	22.3	13.6	4.5

a/ Includes horsemeat.
Source: U.S. Dept. Agr.--FAS Bull. FLM 2-73.

Table 4. Number of people who could theoretically be fed for one day by protein from various sources, based on production from 1 hectare of land in 1 year, assuming 60 grams protein intake per capita per day.

Protein source[a/]	Number of people
Beef	190
Pork	319
Poultry	457
Milk	583
Rice (white)	2,469
Cottonseed	1,793
Peanuts (groundnut)	2,536
Wheat flour (white)	2,712
Sesame	2,620
Corn flakes	2,828
Rye flour (whole)	3,186
Sunflower kernels	3,314
Wheat flour (whole)	3,391
Oat meal	3,445
Corn meal (whole)	3,536
Rice (brown)	3,926
Dry beans	4,315
Potatoes	5,239
Split peas	6,901
Soybeans	9,075
Algae	43,200-154,000
Yeast	3,275,000

a/ Animal protein data calculated from data in D. Catron, Comparative Proteins. University of Missouri. 1967.
Other data based on U.S. Dept. Agr. world average yields, 1971.

Figure 1 shows the efficiency of nitrogen conversion through feeding protein sources (largely vegetable) to animals. For an approximation, it takes 4 to 5 lb protein in the form of animal feed to produce 1 lb protein in the form of chicken meat. For swine it takes 7 lb protein in the form of feed to produce 1 lb meat protein. To convert feed to milk protein, it takes approximately 4 lb protein in feed to produce 1 lb protein in milk. Looking at the situation in another way, Fig. 2 illustrates in a general way how man competes for some types of protein that are used in supplemental protein feeding, namely, protein concentrates such as are supplied by the soybean, sunflower, and so on.

Tables 5, 6, 7, and 8 illustrate the improvement in nutritional value of feed before and after soy protein concentrates (as well as other concentrates) were available in quantity in the United States. While other factors such as better knowledge of animal nutrition with regard to vitamin and mineral requirements, the advent of antibiotics, and so on, contributed to the improved feed conversion and weight gains of various animals, there is no question that soybean meal contributed greatly to this improvement. For example, in broilers (Table 5), when one compares the 1931 ration with the 1969 ration the average increase in size of broilers in an 8 wk feeding period was 35 percent using about 23 percent less feed. Similar results are indicated for turkeys, swine, and beef cattle.

Tables 9 and 10 show soybean production and average yields in selected countries for approximately the past 10 years. Unfortunately, few data were available on production of soybeans in Africa and Western Asia. The United States is the largest exporter of soybeans, soybean meal and soybean oil. The quantities of soybeans and soybean meal exported to Western Asia and to Africa have been relatively small, but the export of soybean oil to these areas has been significant. Table 11 shows that over the years a substantial amount of soybean oil has been exported from the United States to Africa and western Asia. During the past 2 years there appears to have been a substantial drop in export, which undoubtedly is primarily due to the extremely high prices for oil which began to prevail during the 1972 crop year and have continued.

Soy protein-containing products have been used for centuries as food products in Asiatic countries. With the advent of solvent extraction and other technology, a variety of protein-containing products have been produced in the United States and elsewhere. In Japan, where traditional Oriental foods are still being used, they, too, are developing new ways of taking advantage of the protein from the soybean.

In the United States, processed dehulled whole soybeans are being marketed as snack items, although this use of soybeans still is relatively small. The major soy protein-containing products are defatted soy flour and grits, full-fat soy flour, expeller produced low-fat soy flour and grits, soy protein concentrates, isolated soy protein, texturized soy protein, and spun protein fibers. Tables 12 and 13 show the typical composition of these products.

Table 14 shows the estimated current annual production of the various edible soy products in the United States. The production of soy flour and grits has essentially doubled in about the last 10 years. For practical purposes the other products were essentially at zero level of production 10 years ago.

Figure 3 shows the general steps involved in producing various products from the soybean. In processing soybeans to produce meal and oil, the steps through solvent extraction are exactly the same as for producing flakes for making edible products. However, if soybeans are to be processed for producing edible products the plant should be designed to permit good sanitation practices. Generally, it is necessary to do a better job of bean cleaning for edible products than for producing meal for animal feed purposes. When a plant is operated for producing oil and meal for animal feed, the desolventizing is usually carried out in one unit referred to as a desolventizer toaster. In this unit the solvent is removed from the solvent wet flakes and the meal is heat processed to destroy antigrowth factors, such as antitrypsin factor, and to improve the nutritional quality of the protein. In the desolventizer toaster unit, the meal is heat processed in such a way that the urease activity, when determined by a standard procedure, is less than 0.15. There is a general correlation between urease activity and water dispersible protein, as well as antitrypsin activity.

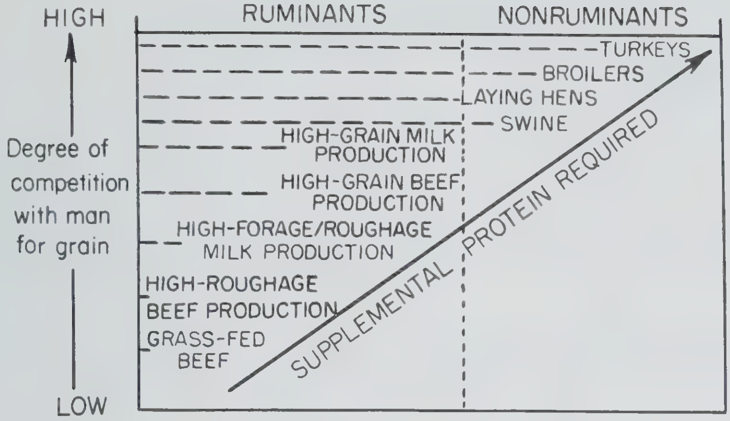


Fig. 1. Competition of food-producing animals for man's food supply. (From D.V. Catron, *Comparative Proteins*, University of Missouri, 1967.)

STEP

1. AIR N_2 $\xrightarrow{90\%}$ FERTILIZER N
2. FERTILIZER/SOIL N $\xrightarrow{50\%}$ PLANT PROTEIN
3. BALANCED RATIONS $\xrightarrow{6\text{-}27\%}$ ANIMAL PROTEIN

	AV.	BYERLY (1965)	WILCKE (1966)	PRESTON (1966)
DAIRY COW (MILK)	27	30	23	28
BROILER	22	25	18	24
HEN (EGGS)	22	20	23	23
SWINE	16	19	13	17
BEEF PRODUCTION	6	5	5	8

Fig. 2. Comparative efficiency of nitrogen conversion of food-producing animals. (From D.V. Catron, *Comparative Proteins*, University of Missouri, 1967.)

Table 5. Broiler growth and feed conversion in eight weeks.

Type of ration	Weight gain (kg)	Feed conversion[a/]
1931	1.28	2.75
1969	1.73	2.10

a/ Amount of feed per unit gain.

Table 6. Turkey gain and feed conversion.

Type of ration	Gain from hatch to 6 wks (kg)	Feed conversion[a/]
1930	0.975	2.30
1969	1.260	1.73

a/ Amount of feed per unit gain.

Table 7. Swine growth and feed conversion.

Type of ration	Days fed	Average initial weight (kg)	Average final weight (kg)	Average daily gain (kg)	Feed conversion[a/]
1908	105	18.2	28.4	.095	8.11
1958	105	18.7	96.4	.74	3.18
1929	79	20.5	62.7	.54	3.29
1969	79	20.5	72.9	.66	2.92

a/ Amount of feed per unit gain.

Table 8. Cattle growth and feed conversion.

Type of ration	Days fed	Initial weight (kg)	Final weight (kg)	Average daily gain (kg)	Feed conversion[a/]
1908	252	189.8	392.3	.80	9.0
1958	252	170.7	459.4	1.14	6.3

a/ Amount of feed per unit gain.

Table 9. Soybean production in selected countries.

Country	Production (1,000 mt) 1962-1966 average	1971	1972	1973 (indicated)
United States	20,920.0	32,005.0	34,915.0	42,633.0
Romania	6.21	165.0	186.0	234.0
Yugoslavia	8.98	4.0	5.99	--
Bulgaria	--	--	--	15.0
Russia	436.8	535.0	260.0	400.0

Source: See Table 1.

Table 10. Soybean yields in selected countries.

Country	Yield (mt/ha) 1962-1966 (average)	1971	1972	1973 (indicated)
United States	1.634	1.849	1.883	1.883
Romania	0.686	1.123	1.708	--
Yugoslavia	1.358	0.827	1.641	--
Bulgaria	--	--	--	1.7
Russia	0.511	0.619	--	--

Source: See Table 1.

Table 11. United States soybean oil exports to West Asia (west of ca 90° E long.) and Africa, 1970-1974.

Region or country	Soybean oil exported (1,000 mt)[a] 1970[b]	1971	1972	1973-74 (Oct. 1-Mar. 1)
West Asia[c]	335	257	160	55
Africa	96	128	30	30

a/ Each 1,000 mt of soybean oil = ca 5,600 mt soybeans.

b/ Year begins October 1.

c/ Does not include People's Republic of China and Israel.

Source: U.S. Dept. Agri.--FAS Bull. FFO 6-74.

Table 12. Typical percentage composition of soy protein-containing products.

Item	Whole soybeans	Defatted soy flour	Soy protein concentrates	Soy protein isolate
Moisture	10	7.0	4.0	4.0
Protein	38	52.0	68.0	92.0
Fat	18	1.0	1.0	0.1
Fiber	5	3.5	4.5	0.1
Ash	5	6.0	5.0	3.5
Soluble carbohydrates	12	12.5	2.0	0
Insoluble carbohydrates	12	18.5	28.0	0.1

Table 13. Typical percentage composition of full-fat and low-fat soy products.

Item	Full-fat	Low-fat
Moisture	5.5	5.0
Protein	40.5	50.0
Fat	21.0	6.0
Fiber	2.3	2.8
Ash	4.5	6.0
Carbohydrate	26.2	30.2

Table 14. Estimated current annual production of various edible soy products in the United States.

Product	Estimated annual production (1,000 mt)
Soy flour and grits	340-450
Soy protein concentrates	30
Isolated soy proteins	25
Textured soy proteins	90
Spun protein fibers	8

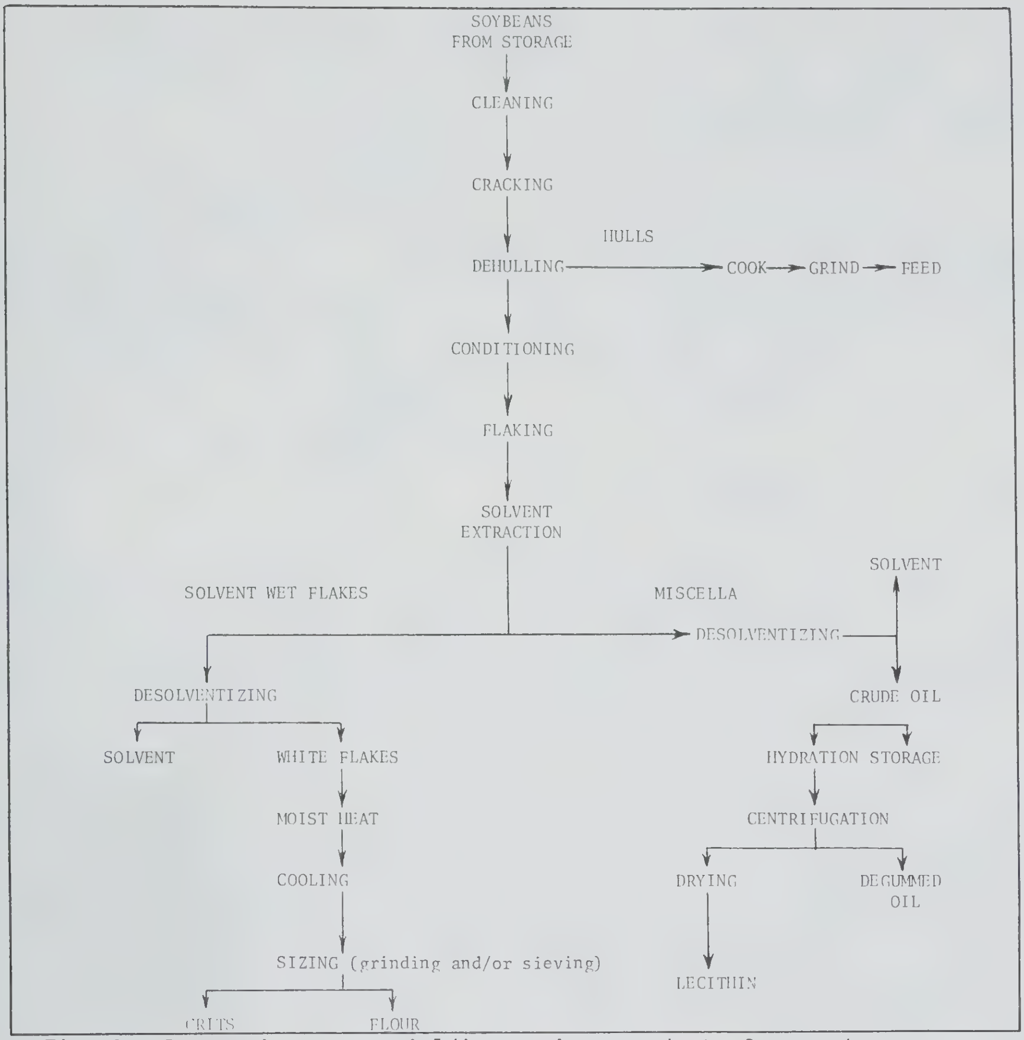
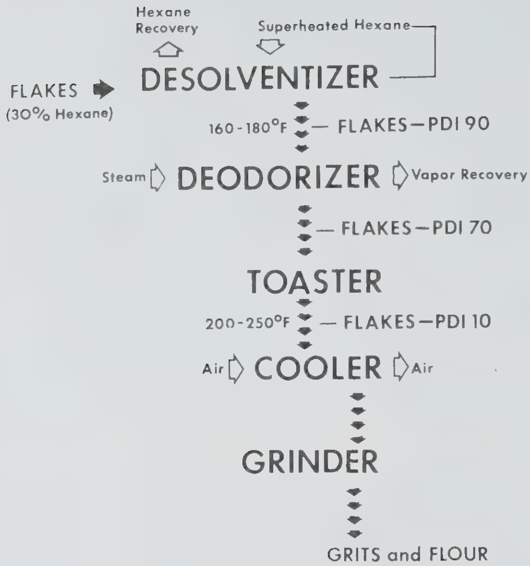


Fig. 3. Processing steps yielding various products from soybeans.

A number of terms have been used to designate the amount of protein in the product that is water dispersible, but the more commonly used terms are PDI (protein dispersibility) index and NSI (nitrogen solubility index). The procedures used for determining these values have been published in Official and Tentative Methods--American Oil Chemists' Society. For purposes of this discussion, the term PDI will be used. When the urease activity of a heat processed soy product is below 0.15, the PDI will generally be below about 30, which represents the percentage of the total protein in a product that is dispersible in water under the conditions of the determination. It is possible to overheat a soybean meal and harm the nutritional value of the protein. Generally the product should not be heat processed below a urease activity of around 0.05 or a PDI below about 5, if one wishes to have the optimum protein nutrition.

The use of soy flour and grits, soy protein concentrates, and soy protein isolates in foods in the United States has primarily been to take advantage of certain functional characteristics of these products as ingredients in food processing, with nutritional value being of secondary interest. Naturally there have been exceptions to this, where nutritional value is of prime importance. This situation is changing. While functional value is still important, the nutritional considerations are now receiving much more interest. In regard to soy flour products, the functional characteristics are influenced by the PDI and particle size. Soy flour and grits are differentiated on the basis of particle size. Products that are ground to pass a 100 mesh U.S. sieve or finer are referred to as flour products, and those that are more coarsely ground and screened are referred to as grits. Figure 4 is a general scheme for operation of the desolventizer-deodorizer-toaster system to produce soy flour and grits.



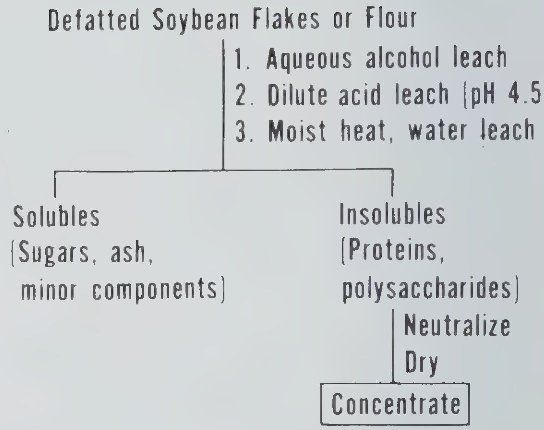


Fig. 4(left). Scheme for operation of desolventizer-deodorizer-toaster system in the production of soy flour and grits. Fig. 5(right). Scheme for production of soy protein concentrate. (Both from *J. Amer. Oil Chem. Soc.*, January 1974.)

Soy protein concentrates, by definition, are products that have been processed to contain greater than 70 percent protein on a dry basis. The general scheme for their production is shown in Fig. 5. Three procedures are currently being used to manufacture these types of products. In one process, aqueous alcohol is used to extract the soluble carbohydrates, minerals, and other components. The concentrate produced by this procedure is generally considered to have the least beany flavor. Regardless of the PDI of the flakes used as starting material in this process, the proteins are denatured so that the PDI of the finished product is in the range of 5 to 15 percent. The concentrate produced by this process has very little beany flavor and does have the ability to absorb moisture and fat. It is used in breads, meat products, breakfast cereals, calf milk replacers, and so on.

Soy protein concentrates produced by the acid leach process are usually neutralized to a pH of about 6.8 and spray dried. The acid leach concentrates, when so neutralized, have PDI values close to those of the original flakes or flour used for processing. This type of concentrate is used in a manner similar to the alcohol leach product, but does not seem to have a market in calf milk replacers, primarily due to higher price.

In the third process for producing concentrates, the flakes or flour are heated to such a point that the proteins are almost completely denatured so that straight water wash will remove solubles and give a product that has water and fat absorption properties, but few other functionality characteristics.

Other processes have been developed, including the use of mixed solvents for removal of solubles which are said to give products with better flavor and functionality characteristics; new plants are being built to utilize them. The primary advantage of the concentrates over regular soy flour and grits is the higher protein concentration and better flavor. In the manufacture of these products, the soluble portion, if not recovered, constitutes a water pollution problem. Most companies producing these products concentrate the solubles and add them back to meal for use in animal feeds.

Figure 6 gives a general flow sheet for the manufacture of isolated soy proteins. These products are high in protein, are generally bland in flavor, and have good functionality. Depending on the process, there are differences in functional characteristics of the isolates. Since isolated soy proteins are essentially free of carbohydrates, fiber, and fat, and also have a variety of other properties different from concentrates and soy flour, they can be used more successfully in imitation dairy-type products. Soy protein isolates also find extensive use as a binder and emulsifier in comminuted meat products. Figure 7 shows the products from the soybean and uses of the various products in the United States.

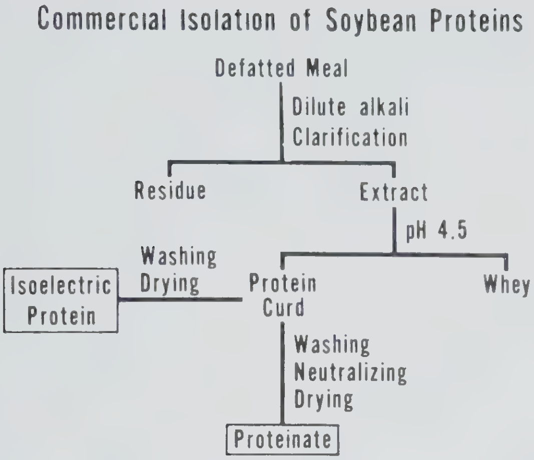


Fig. 6. Process for preparation of isolated soy proteins. (From *J. Amer. Oil Chem. Soc.*, January 1974.)

If soy flour or grit products are to be used as ingredients in foods that receive no appreciable heating during their processing, the soy flour should be made from heat treated flakes having a PDI of below about 30. The reason is that, if the PDI is higher, the optimum nutritional value is not obtained due to the presence of the antitrypsin factor. In the case of food products that are heat treated during the manufacturing process or that will be heated during preparation of the food before consuming, the higher PDI types of soy flour may be used to take advantage of the functional characteristics these products possess. Heat treatment during processing of these products in manufacture, or cooking before consumption, destroys the antitrypsin factor so the nutritional value of the products is satisfactory.

Textured soy protein products that are produced by a thermoplastic extrusion process have come into existence during the past few years. Figure 8 gives a diagrammatic sketch of the process used for making these products. Textured soy proteins are produced from defatted soy flour, have a laminated structure, and are produced as dry products which, when rehydrated, have textural characteristics similar to meat. They may be colored, flavored, and fortified with vitamins and minerals. These products have found acceptance as a partial substitute for ground meat and were approved for use in the School Lunch Program in the United States in 1971. The dry textured soy protein products are hydrated with water using two parts of water for each part of textured soy protein. The hydrated product is then mixed with ground meat on the basis of 30 parts of the hydrated products with 70 parts of meat. During the 1971-1972 school year, the usage on the dehydrated basis was a little over 3 million kg and last year was estimated at 27 million kg. The savings over the purchase of all meat in the 1973 School Lunch Program is estimated at $40 million.

These products also are being used in ground meat products being sold direct to consumers. Recently, packaged, flavored, and colored textured soy protein products have appeared on the market as complete replacements for meat in sauces, casseroles, and so on, where ground meat products are usually used. Estimates by the U.S. Department of Agriculture are that by 1980 these products, including soy protein concentrates, isolates, and soy flour and grits, could be equivalent to 8 percent of the U.S. total red meat products. Studies in humans have shown that use of textured soy protein products in combination with meat gives nutritional results that are not essentially different from those obtained with 100 percent meat products.

Another, more sophisticated, type of textured soy protein product is produced from isolated soy protein when the dispersion of the protein is forced through very fine openings into a coagulating bath whereby fibers are formed. These products are then pulled off in what are referred to as "tows" and processed to make different types of simulated meat and fish products. Figure 9 represents the scheme for the soy protein fiber process.

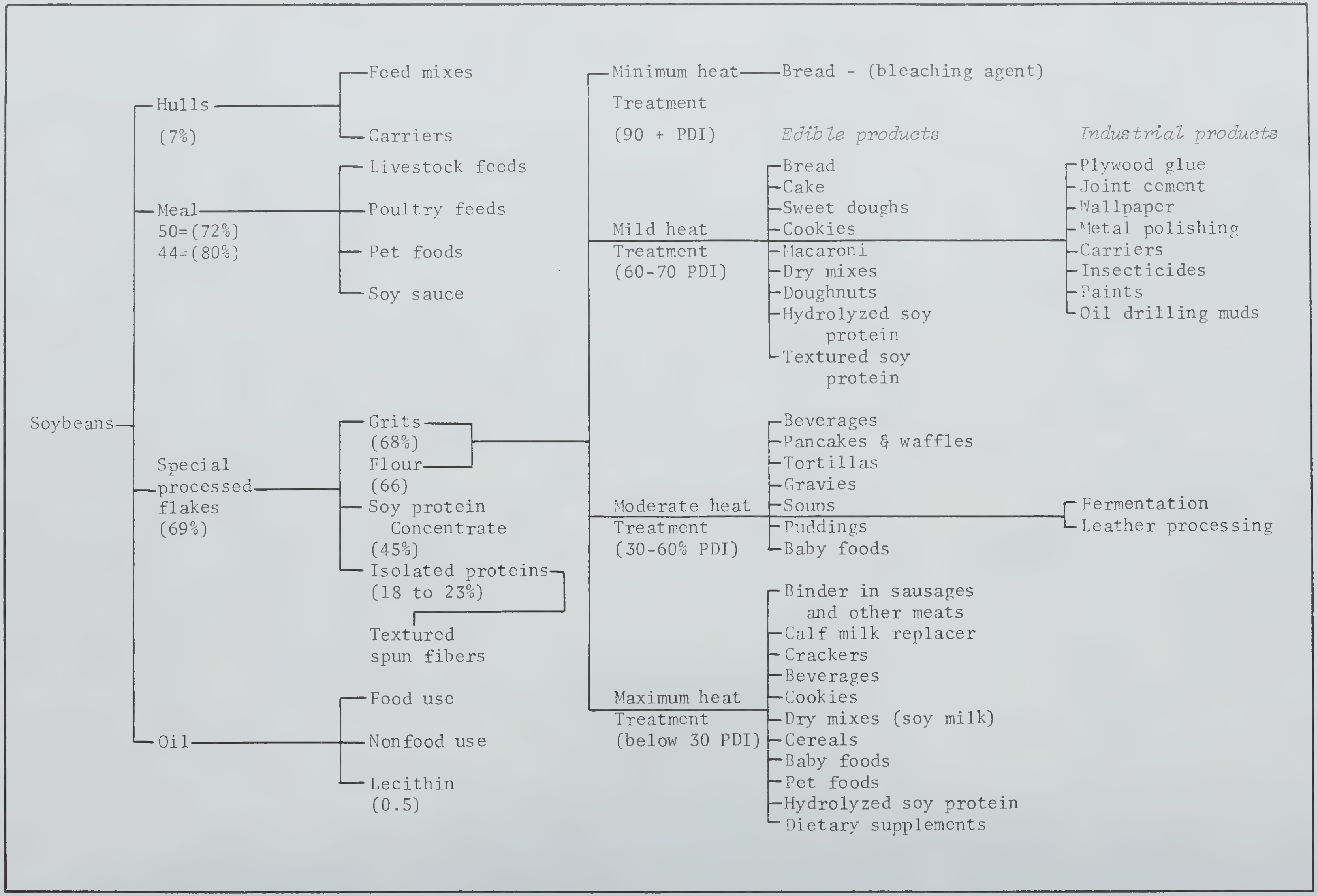


Fig. 7. Products from the soybean and their uses in the United States. (Numbers in parentheses indicate typical yield from soybeans.)

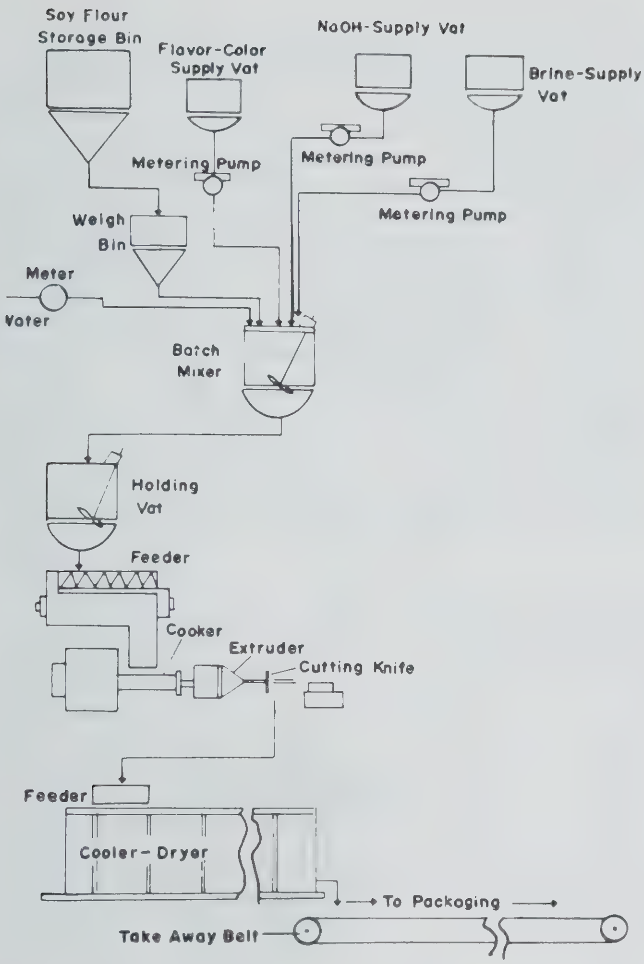


Fig. 8. Thermoplastic extrusion process for making various soybean products. (From *J. Amer. Oil Chem. Soc.*, January 1974.)

These products are available to consumers in the U.S. as bacon-type bits, non-meat sausage-type products of both the pattie and link type, and as slices simulating ham. The bacon-type products are a dry flavored product used wherever fried bacon bits might be desired. The flavored, simulated meat fiber-type products have recently appeared in supermarkets as a frozen item to be warmed and eaten in a manner similar to meat. There are also simulated chicken, ham, beef, and other products being sold as frozen items in the institutional field to be used as complete or partial replacement for meat in any way that a cubed or chopped meat product might be used. A major meat processor is test marketing a frankfurter-type product where reportedly 50 percent of the protein is isolated soy protein. This product is apparently being well accepted in the test markets, and may eventually be marketed on a national basis.

It has been widely accepted that soy protein products, by themselves, have excellent nutritional protein. Since soy protein has a higher lysine content than is necessary to satisfy the amino acid requirements as set forth in the Food and Agriculture Organization pattern, it can be used to improve protein quality of cereal proteins that are limited in lysine content, resulting in a cereal product with higher protein quality and increased protein content.

The major problem in the use of defatted soy flour and grits in foods from the standpoint of levels of use has been that of flavor. As a result, further processing to produce soy protein concentrates and isolates with less of a flavor problem has resulted. In textured soy protein products, the processing does give some flavor improvement but the products still are not perfect from that standpoint. When textured soy protein products are used in combination with meat, it is common practice to add seasoning ingredients that "cover up" the undesirable soy flavor.

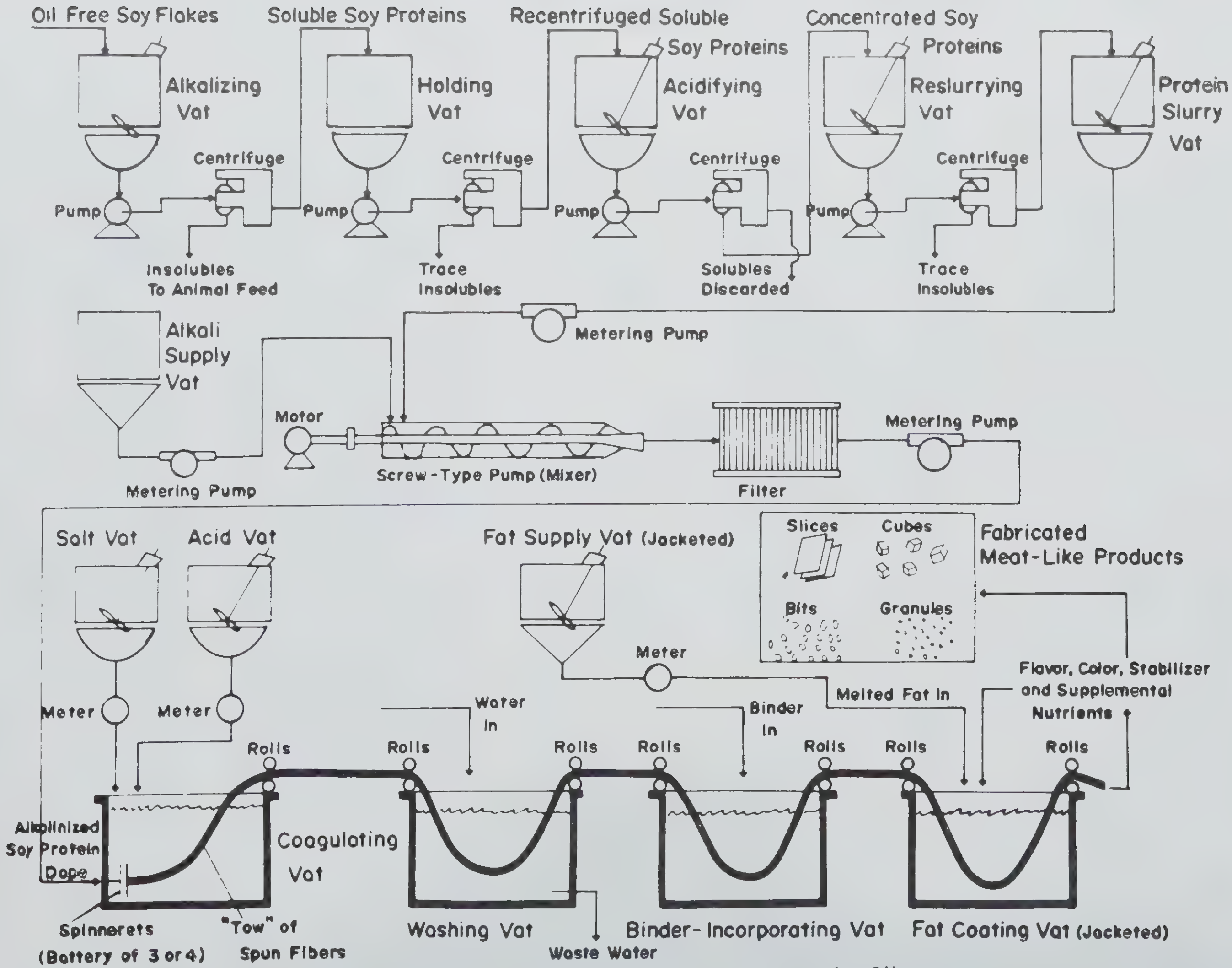


Fig. 9. Scheme for production of textured soy protein fiber.
(From *J. Amer. Oil Chem. Soc.*, January 1974.)

Scientists agree that the flavor problem in making defatted soy products results mainly from current production methods where the beans are cracked and flaked, and the lipoxygenase system is such that oxidative reactions take place with the fat tied to the protein as lipo-protein. A flavor develops which is not easily removed during subsequent operations. As a result of this finding, in making full-fat and low-fat soy flour the beans are heat processed before cracking and further processing, in order to inactivate the lipoxygenase system. The full-fat products which are produced by such heat processing of the beans, followed by hull removing and grinding, do not develop the beany, bitter flavor, but, depending on the degree of heat processing, have a pleasant nutty characteristic. This type of flour is being used in a variety of baked products, to a limited extent in calf milk replacer products, and as a partial replacement for peanut butter in certain baked products and confectionery items. Full fat soy flour is also being used in soymilk products used for feeding babies allergic to cow's milk.

Another type of soy flour with good flavor is low-fat soy flour which is produced by heat processing the beans in a manner similar to that used for making full-fat soy flour, followed by dehulling and expelling part of the oil to yield a soy protein-containing product with about 6 percent fat and 50 percent protein. This type of product is being used in comminuted meat items, pet foods, baked products, soymilk, and other food products where the presence of the fat is not detrimental.

Other Uses of Soy Products

A major use of soy protein-containing products in the United States is in pet foods in a variety of different products including canned, semi-moist, and dry. The dollar retail sales volume of these products is estimated in the range of $1.6 to $2 billion dollars. While there is no general reporting in the United States on quantities of soy protein products used, it is estimated that the overall use of soy as meal, grits and flour, and textured soy proteins is in the range of 330,000 to 450,000 metric tons per year. On a protein basis, this undoubtedly makes up over 50 percent of the total protein consumed by pets, mainly dogs.

In many food products, soy lecithin is used as an additive. In the United States where soy flour and lecithin are used as ingredients in the same food product, it is common practice to add the lecithin to the soy flour at levels up to 15 percent as a convenient way of handling the lecithin. By way of general interest it is estimated that soy lecithin production in the United States is in the range of 34,000 to 41,000 metric tons, on a crude lecithin basis. Lecithin of various types is used in a wide variety of food and industrial products.

For many years soymilk products have been available as dry, canned, or liquid products for feeding babies who are allergic to cow's milk, and for others, such as vegetarians and certain religious groups, who do not desire animal protein. It has been estimated that in 1973 about 10 percent of the infants in the United States were fed formulas based on soy. Twenty-five or thirty years ago infant formulas were developed based on producing soymilk directly from beans, with full-fat soy flour and low-fat expeller-type soy flour. While these products are still being produced, in the 1960s, when isolated soy proteins as proteinates were available, it became possible to make a better flavored, nicer looking product with good color, and better general acceptability insofar as the mother was concerned. These products are formulated in a way that gives good caloric distribution among protein, fat, and carbohydrates, with the addition of methionine, minerals, and vitamins.

The soymilk products based on isolates, for feeding infants, result in better formed and less odorous stools. In the soy flour products, the presence of stachyose and raffinose results in the development of microbial flora, different from that produced if these carbohydrates are not present. In manufacturing soy protein isolates, these carbohydrates are removed.

In the beverage product area, sterilized soymilk products have been sold for many years in Asian countries. In Hong Kong, a product known as "Vitasoy" and produced by Hong Kong Soyabean Products Company reportedly outsells carbonated beverages. It was projected that about 150 million bottles were sold in 1973. These products are made from whole soybeans with sugar, flavor, vitamins, and minerals added.

For a number of years the U.S. government has purchased a product known as "CSM," which is a corn-soy-nonfat milk product. But with the shortage and increased prices of nonfat milk, a new product has been formulated based on sweet cheese whey and either full-fat or low-fat soy flour, with fat level adjustment, along with other additives, which is intended

for use as a beverage in the Agency for International Development (AID) program. This project is just now getting under way and it is projected that government purchases will reach about 10 million pounds per month in the next 2 to 3 years.

Soy Flour Products

For at least 25 to 30 years, soy flour products have been used as a partial replacement for milk in milk replacer products for feeding young animals, with perhaps 95 percent of these products being used for feeding calves. Soy protein concentrates are also widely used in calf milk replacer products, and there is a limited amount of isolated soy protein used in such products. The isolates are not used so much for nutritional value, but rather to take advantage of certain functional characteristics in producing these products.

In feeding baby calves for herd replacement, soy flour generally is used up to levels of around 10 percent. Baby calves are allowed to feed on the mother cow for 2 or 3 days and then are fed on milk replacer products for about 3 to 4 months at which time they begin to get solid feed. In calves raised for veal, rapid weight gain is wanted, so the animals are essentially force fed for 10 to 12 weeks. Until recently very little soy protein was used in feeding veal animals. However, it is reported that due to the high prices for nonfat milk, small amounts of soy flour are used in some products. In producing animals for herd replacement, there is less interest in rapid gain and more interest in bone structure, so the mineral content, particularly calcium, is important.

Some milk replacer products are used for feeding baby pigs, where they are fed on colostrum for about 3 days and then fed a milk replacer. After about two weeks they are switched to a high-milk pellet which will contain whey and nonfat milk and may contain 5 to 10 percent soy flour. Some liquid products are fed to dogs and may consist of combinations of whey, sodium caseinate, and soy flour, but these are special products usually sold through veterinarians.

In the baking field one type of soy flour which has been used extensively in the United States and Europe for many years is that referred to as "enzyme active." It is produced as a defatted product and the desolventizing is carried out in a manner that involves very little moist heat so that protein denaturation is at a minimum and the enzyme activity is retained. Another enzyme active flour is the full-fat type, made by cleaning the beans, dehulling, and grinding them to a fine flour. The enzyme active flour is usually used at a level of 0.5 to 0.75 percent based on the wheat flour. This flour has a beany, bitter flavor, but at the levels of use and through the heating of the product during baking, this flavor does not seem to appear in the final product.

The reason for using enzyme active flour is to take advantage of the lipoxidase enzyme systems whereby a bleaching effect is exerted on the flour pigments. The soy lipoxidase enzyme system results in the formation of hydroperoxides which in turn react to give a bleaching effect, with improvement in crumb color. There also is improvement in the crumb softness, keeping quality, and flavor. Other types of soy flour used in baking bread, cakes, and so on are types that have been heat processed to some extent and do not have the lipoxidase activity, but still have a PDI of 60 to 70. These flours are used primarily for other functionality characteristics such as water absorption, and are used at higher levels.

Factors Influenced by Soy Flour in Various Products

It has been common practice in the United States to use nonfat milk solids in breads at levels from 3 to 6 percent, to improve crust color and nutrition, and to give what some people feel is better flavor. Ten years or so ago nonfat milk was available in the United States at around 15¢ per pound. During 1973 prices reached almost 70¢ per pound and there were problems of supply. This past year there has been some easing of supply with substantial government purchases of surplus and prices in the range of 57¢ to 60¢ per pound. It is felt, however, that in the long run we still will have shortages and higher prices. As a result, we now have an example of economics coming into play where blends of cheese whey, nonfat milk solids, sodium caseinate, and soy flour are used as nonfat milk solids replacement. These blends may sell at one-third to one-half the price of nonfat milk solids and are produced in a way that allows their use as direct replacement for nonfat milk. This is not only true in the baking field, but in other areas such as confectionery, sauces, and meat products industries.

When soy flour is used at higher levels than 1 or 2 percent in bread, based on the wheat flour, as the soy flour level increases, the volume of the finished loaf gradually decreases in proportion to the amount of soy flour added. In recent years it has been found that when certain emulsifiers are added along with the soy flour, this effect on volume can be overcome. The emulsifiers of the stearoyl-2-lactylate type permit the production of good loaves of bread using as high as 15 percent soy flour. It is claimed that use of this type of emulsifier also helps markedly to overcome the undesirable flavor usually associated with use of high levels of soy flour in bread.

The normal protein efficiency ratio (PER) of white bread in the United States ranged from 0.7 to 1.0 with a protein content of about 8 percent. When bread is fortified with about 6 percent soy flour, the PER is increased to about 1.3 and the protein content to 10 percent. With 12 percent soy flour added, the PER is increased to 1.9 and the protein content to about 11.5 percent. In cookies, in the United States, the protein content is usually about 5 percent and the PER around 0.5. When cookies are produced using 12 percent soy flour, based on the wheat flour, the protein content increases to about 8 percent and the PER to about 1.5.

The price of wheat flour in the United States is currently higher than defatted soy flour. While we can expect variation in prices, it would appear that, at least for the foreseeable future, fortification of wheat flour to increase protein content and improve the protein quality of bread can be carried out at a lower cost than using wheat flour alone. When soy flour is used in baked products, it is necessary to make some adjustments in the processing because mixing time is usually decreased. One should add about one additional pound of water for each pound of soy flour used, over what normally would be used in preparing the food product.

Soy flour products can also be used to fortify pasta or macaroni-type products. Although the addition of soy flour does result in some color and textural changes, pasta products are being produced using soy flour to improve the nutritional character of products being used in overseas programs and in school lunch programs and other feeding programs in the United States. In pasta products in the United States, durum flour is the ingredient of choice. Feeding studies have shown that when 100 percent durum is used the PER is about 1.27. With 12.5 percent soy flour the PER increases to 1.94 and with 25 percent soy flour to 2.39. The soy fortified products contain approximately 50 percent and 100 percent more protein than the unfortified product, respectively, so the consumer is not only increasing his protein intake but is getting a much better quality protein.

In certain comminuted meat products in the United States there are Standards of Identity whereby, in a standard product, the quantity of soy that may be used is limited. For example, in frankfurters, soy flour or soy protein concentrates may be used up to a maximum of 3.5 percent and isolates are limited to 2 percent. However, in meat products that do not have a Standard of Identity there is no limitation to the usage, but the ingredients used must be listed on the label in order of quantity in a given food product. The level of use in so-called "nonspecific" meats depends on the characteristics and quality desired in the product to be marketed.

With the shortages and high prices for dairy products, there is considerable activity in the possible use of soy beverages or soy milk-type products as partial or complete replacement in all types of dairy foods, including cheese, ice cream, yogurt, and so on.

It appears that soy protein products, which once were considered as "ersatz" items, now are being recognized as good food ingredients and will stand on their own merits as good nutritional ingredients to be used in foods, or as foods by themselves as a replacement for meat and dairy products in the human dietary.

The Industrial Production of an Organoleptically Acceptable Soybean Milk

S.I. da Costa and D.B. Arkcoll

Soybeans have not been used to any great extent by most developing countries for two reasons. First, few soybeans are produced by these countries, making them dependent on other countries for supplies. Second, many unfavorable reactions to the taste of soybeans were formed from the uncooked defatted flours made available to such countries in the past.

Brazil is fortunate in being one of the few developing countries that has areas far enough from the equator to be suitable for growing commonly available varieties of soybeans. As a result, production has increased rapidly in the last 5 years to the point where the country is now the second largest producer in the world. Although most of this crop is extracted and exported, there is obviously considerable interest in using it locally to improve the nutritional status of a large sector of the population.

Among the various projects that are being considered is the production of soymilk. There is an inadequate supply of cow's milk in most parts of the country at present and thus soymilk is seen as a convenient replacement that can be readily incorporated into the school lunch program. It is also considered an excellent vehicle for the vitamin and mineral supplementation that is part of the government's fortification program.

Development of a Process

Soymilks of strong flavor have been made for centuries in the Orient by crushing and filtering soybeans with water. Much research over the last 10 years has concentrated on the causes and elimination of these unpleasant flavors. Lipoxidase activity is generally blamed and an unpleasant volatile ethyl vinyl ketone which it produces has been isolated (1). In fact the dry bean itself is very unpleasant (2) and already contains most of the volatile substances and carboxylic acids that are responsible for the poor flavor of products made from it. Thus the prime object of almost all work on soybeans is to eliminate these compounds and prevent the formation of others. Cooking the beans or their products under moist conditions appears to do this, especially if cooking occurs quickly so that enzymes and other compounds released upon rupture of the cells have no time to act or react.

Thus we initially ground dry dehulled beans with 10 volumes of boiling water in a Ritz-type mill before boiling for an additional 10 minutes. However, tasting panels appeared unable to tell the difference between milk made by this method and milk made by soaking dehulled beans in water for 90 minutes before grinding with boiling water. Nor could an improvement in flavor be detected when beans were soaked in caustic soda or sodium bicarbonate It seems that undesirable flavor development is not a serious problem during the soaking of dehulled beans even when beans are slightly damaged during harvesting and splitting. Only 90 minutes of soaking are needed for almost complete imbibition of water which leads to a considerable saving in power consumption of the mill.

Further heating proved necessary after the hot-water milling to ensure adequate destruction of antinutritional factors. This was also believed to reduce the slight astringency of the milk and it improved the separation of solid particles in the continuous centrifuge. This part of the process resembles that developed by Cornell University as outlined by Bourne (3).

The Final Process

The final stage is the production of long-life milk. As part of our soy flour program we have made a soy flake from boiled beans that can be transported readily and then reconstituted into an acceptable milk.

S.I. DA COSTA, Head; D.B. ARKCOLL, Advisor: Lipids and Proteins Section, Institute de Tecnologia de Alimentos (ITAL), C.P. 139, Campinas, S.P., Brazil.

A layout of the production plant is shown in Fig. 1. Beans of the variety that gave the best flavored milk in a testing trial are split by a disc mill. Halved beans are then separated from their shells and embryos by a sieve and air blast. After soaking in three volumes of water for 90 minutes, excess water is drained off and the beans are fed to the mill hopper. They are then metered into the mill together with enough steam to maintain the temerature above 95°C and with a 10:1 ratio of water to dry beans. The slurry is pumped directly into a thermoscrew where it is injected with steam for 10 minutes. It is then pumped into a continuous disc centrifuge which has an automatic intermittent solid discharge. The soymilk is collected in a mixing tank into which various formulations are added. The final product is then homogenized and flash sterilized before being aseptically packaged. Figure 2 shows the crude composition of the soybean fractions.

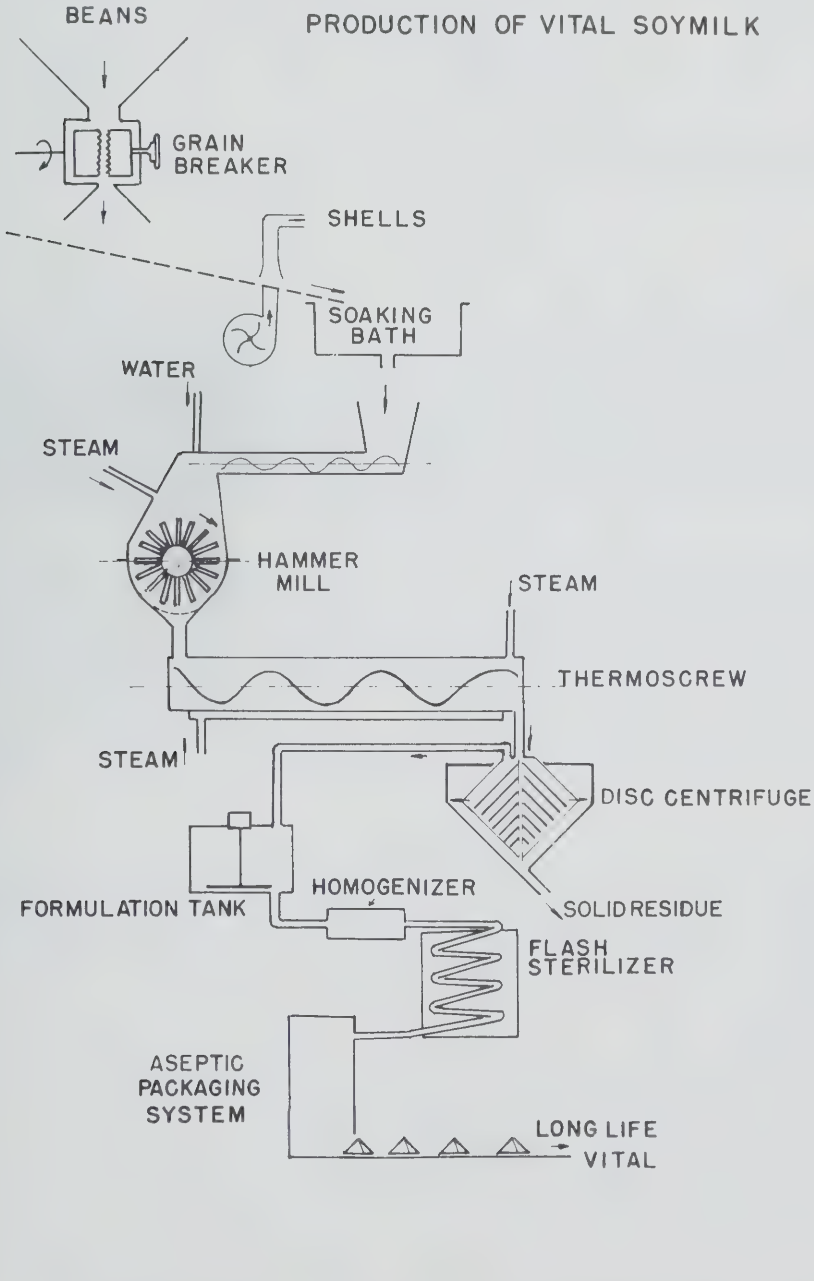


Fig. 1. Diagram of production plant for making long-life soymilk (VITAL).

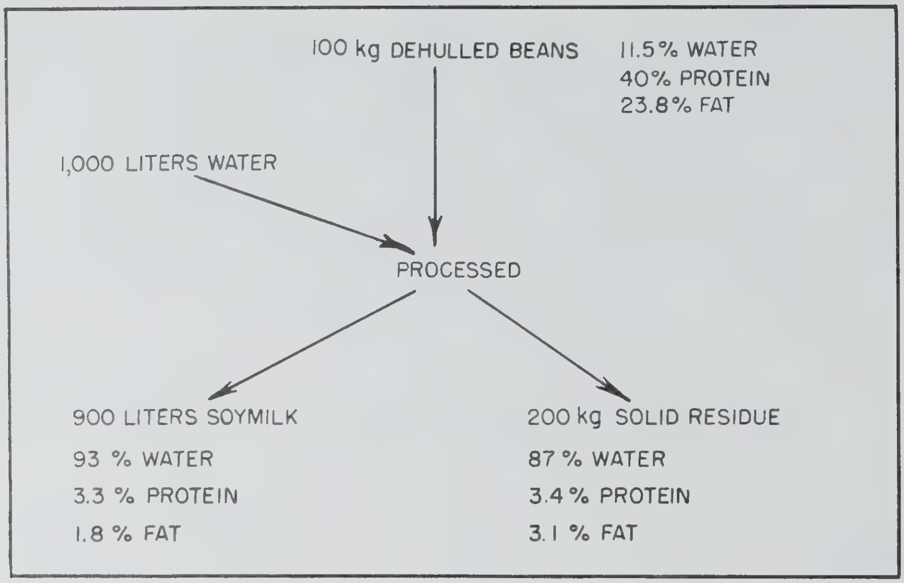


Fig. 2. Flow diagram of production of soymilk from dehulled soybeans.

Formulation and Acceptability of Products

Tasting panels were used to select the best levels of sugar, salt, carboxymethyl cellulose, and flavor and color extracts. A typical formulation is shown in Table 1. The seven best flavors were then offered to 100 school children between the ages of 7 and 13. They were asked to place the soymilks on a five-point scale ranging from very agreeable to very disagreeable as indicated by a facial hedonic diagram. The results are shown in Table 2. Differences in acceptability were not significant.

Table 1. Composition of a representative soymilk formulation.

Ingredient	Percentage	g/1,000 liters
Sugar	10.0	
Salt	0.2	
Carboxymethyl cellulose	0.08	
Strawberry flavor BR 6603	0.033	
Coloring extract No. 2 I.C.I.	0.025	
Vitamin and mineral mixture		50

Table 2. Acceptability scores for soymilk (VITAL) of different flavors.

Flavor	Score	Coefficient of variation	Taster's description
Strawberry	4.45	25.7	Liked
Chocolate	4.38	26.2	"
Vanilla	4.36	27.8	"
Banana	4.05	33.0	"
Red currant	4.03	35.1	"
Pineapple	3.90	39.8	"
Coconut	3.88	39.0	"

SUMMARY

A soymilk has been made that is readily accepted by school children. Trials are underway to determine whether any long-term problems will develop. The current price of the milk is estimated at 10 to 15 cents (U.S.) per liter not including cost of the vitamin-mineral supplement or giving the residue any value. We are now concentrating on lowering the cost of production and developing food products from the residue. A coconut biscuit is showing some promise. Further developments depend on this work and the extent to which the government is prepared to subsidize the school lunch program.

REFERENCES

1. Mattick, L.R., and D.B. Hand. 1969. Identification of a volatile component in soybeans that contributes to the raw bean flavor. J. Agr. Food Chem. 17:15-17.

2. Rackis, J.J., D.H. Honig, D.J. Sessa, and H.A. Moser. 1972. Lipoxygenase and peroxidase activities of soybeans as related to the flavor profile during maturation. Cereal Chem. 49:586-597.

3. Bourne, M.C. 1970. Recent advances in soybean milk processing technology. Protein Advisory Group Bull. 10, pp. 14-21. United Nations, N.Y.

DISCUSSION

R.B. DADSON: Can you tell us something more about the variety of soybean which you found to give you a more acceptable milk product?

S.I. DA COSTA: The variety was bred in Brazil and it is called Santa Rosa.

Simple Processing of Whole Soybeans

L.K. Ferrier

The soybean is an excellent source of major nutrients. About 40 percent of the dry matter in the soybean is protein and it also contains about 20 percent fat. The amino acid pattern of soybean protein approaches the optimum recommended by the Food and Agriculture Organization (FAO) of the United Nations, and the oil is quite desirable because it contains a large proportion of unsaturated fatty acids (Tables 1 and 2). In addition, soybeans appear to be a good source of the required vitamins and minerals (Tables 3 and 4). Thus the soybean has great potential for people who rely mostly upon vegetable sources for protein.

Nearly all of the soybeans produced in the United States and Brazil are processed in oil extraction plants. The oil is generally needed for cooking, mayonnaise, salad dressing, and margarine the world over, and the extracted flake, which contains about 50 percent protein, is used mainly as protein for animal feed. However, as discussed by da Costa in the preceding paper, food uses of the extracted flake are increasing rapidly. Some products that are processed for human food from the extracted flake include soy protein concentrates, isolated soy protein, textured vegetable protein, and soy protein meat analogues.

Another potential benefit is the direct use of whole soybeans with the oil content intact for preparing foods for home use and for commercial processing. The Department of Food Science at the University of Illinois has developed procedures for processing whole soybeans into a number of products which appear to have real potential (1,2,11,12,14,16). The processing procedure is straightforward and uncomplicated. The basic process is described in an earlier publication (11). All of the processes start with field dried soybeans which are carefully cleaned to remove foreign material and damaged or moldy beans. After cleaning, the beans are hydrated by soaking in tap water for at least 5 h followed by precooking (blanching) in boiling water for about 20 to 30 min. For products that require tender blanched beans, 0.5 percent $NaHCO_3$ is added to the blanch water. Products that do not require tender beans can be hydrated and blanched in one operation which requires at least 20 min in boiling water. In some cases the soybeans may be blanched with steam. After blanching, the beans are bland in taste and chewy to tender in texture depending upon the methods followed by hydration and blanching. Water blanched beans will contain 50 to 70 percent moisture whereas steam blanched beans will contain about 20 to 30 percent moisture.

The bland taste of the soybeans produced in this way is directly related to inactivation of enzymes, principally the lipoxygenase enzyme system, in the raw soybean before the tissue is disrupted. When the raw tissue is broken, the enzyme and substrate (oil) are liberated and, provided some moisture is present, a bitter, beany taste develops extremely rapidly. However, the enzyme system is inactivated if the whole soybean is first hydrated and blanched in boiling water or steam. This enzyme inactivation completely prevents formation of any bitter, beany or painty flavor. Blanching simultaneously destroys the trypsin inhibitors, hemagglutinins and other known toxic factors present in the raw beans. If present, these inhibitors would substantially reduce the nutritional quality of the soybeans by inhibiting trypsin and other digestive enzymes. The length of time required to destroy these components decreases with increased moisture content of the soybeans. For example, trypsin inhibitors can be destroyed in rehydrated beans (containing 50 to 60 percent moisture) by boiling for 5 min. However, if dry soybeans are used they must be boiled for 20 min to destroy trypsin inhibitors. Lipoxygenase is inactivated in rehydrated soybeans by boiling for less than 5 min.

L.K. FERRIER: Assistant Professor, Department of Food Science, International Soybean Program (INTSOY), University of Illinois, Urbana, IL 61801, USA.

Table 1. Amino acid composition of soybean protein (g/16 g nitrogen).

Amino acid	FAO amino acid pattern[a/]	FAO data[b/]		Other literature values of the seed[c/]			Full-fat flour[d/]	Concentrate[e/]
		Seed	Cake					
Isoleucine	4.2	4.5	4.8	5.8	6.4	5.5	4.8	4.9
Leucine	4.8	7.8	7.8	7.6	6.6	7.7	7.8	8.0
Lysine	4.2	6.4	6.1	6.6	6.4	6.2	6.5	6.6
Methionine	2.2	1.3	1.4	1.1	0.7	1.4	1.4	1.3
Cystine	4.2	1.3	1.7	1.2	--	--	1.6	1.6
Phenylalanine	2.8	4.9	5.0	4.8	4.8	4.9	5.1	5.3
Tyrosine	2.8	3.1	3.8	3.2	3.1	--	3.9	3.7
Threonine	2.8	3.9	4.3	3.9	3.8	4.0	4.2	4.3
Tryptophan	1.4	1.3	1.5	1.2	1.2	1.7	--	1.4
Valine	4.2	4.8	5.2	5.2	5.0	5.4	5.0	5.0
Arginine	--	7.2	7.1	7.0	6.0	7.5	--	--
Histidine	--	2.5	2.5	2.5	2.3	2.5	--	--
Alanine	--	4.3	4.5	3.8	--	--	--	--
Aspartic acid	--	11.7	11.5	--	--	--	--	--
Glutamic acid	--	18.7	18.5	18.5	--	--	--	--
Glycine	--	4.2	4.5	8.3	--	--	--	--
Proline	--	5.5	5.6	5.4	--	--	--	--
Serine	--	5.1	5.6	5.6	--	--	--	--

a/ Lawrie (9).
b/ Amino Acid Content of Foods and Biological Data on Proteins, FAO, Rome, 1968.
c/ Cravens and Sipes (5).
d/ Iriarte and Barnes (8).
e/ Meyer (10).

Table 2. Fatty acid composition of soybean oil.

Saturated acids (%)	Range	Unsaturated acids (%)	Range
Lauric	0.0 - 0.2[a]	Dodecenoic	
Myristic	0.1 - 0.4	Textradecenoic	0.05 - 0.64
Palmitic	6.5 - 9.8	Hexadecenoic and Palmitoleic	0.42 - 1.60
Stearic	2.4 - 5.5	Oleic	10.9 - 60.0
Arachidic	0.2 - 0.9	Linoleic	25.0 - 64.8
Behenic	-	Linolenic	0.3 - 12.1
Lignoceric	0.0 - 0.1	Arachidonic	traces
Total saturated acids	15.0	Total unsaturated acids	85.0

a/ Includes traces of lower molecular weight acids, ref. Danbert (6).

Table 3. Vitamin content of soybeans.

Vitamin	Mature Bean µg/g soybean	Mature Bean % of RDA[a] 100 g	Meal µg/g soybean	Meal % of RDA[a] 100 g
Thiamine	11.0 - 17.5	100	12.0 - 44.1	200
Riboflavin	3.4 - 3.6	20	2.7 - 3.3	175
Niacin	21.4 - 23.0	12	19.0 40.0	16
Pyridoxine	7.1 - 12.0	--	8.8	--
Biotin	0.8	3	1.1 - 1.7	5
Pantothenic acid	13.0 - 21.5	--	13.3 - 16.0	--
Folic acid	1.9	5	3.7	10
Inositol	2,300	--	2,500 - 3,900	--
Choline	3,400	--	--	--
Carotene (as provitamin A)	0.18-2.43	4	--	--
Vitamin E	1.4	--	--	--
Vitamin K	1.9	--	--	--

a/ RDA = recommended daily allowance. Based on mean value between the two extremes. Assumes all of the mineral is available.

Based on Recommended Daily Allowance from: Food and Nutrition Board, National Academy of Science, U.S.A., for adult male (22-35 years old; 70 kg in weight).

Source: Smith, A.K., and S.J. Circle. 1972. Soybeans: Chemistry and Technology. Vol. 1. Avi Publishing Co., Westport, Conn.

Table 4. Mineral content of soybeans.

Mineral	Mature bean Percentage	Mature bean Percentage RDA/100 g[a/]	Meal Percentage	Meal Percentage RDA/100 g[a/]
Calcium	0.16 - 0.47	37	0.24 - 0.31	34
Phosphorus	0.42 - 0.82	77	0.60	75
Magnesium	0.22 - 0.24	66	0.24 - 0.30	77
	(mg/kg)		(mg/kg)	
Zinc	37	--	55 - 77	--
Iron	90 - 150	66	140	78

[a/] RDA = recommended daily allowance. Based on mean value between the two extremes. Assumes all of the mineral is available.
Based on Recommended Daily Allowance from Food and Nutrition Board, National Academy of Science, for adult male (22-35 years old; 70 kg in weight).

Source: See Table 3.

Boiling is also essential to produce an acceptable texture and, for practical purposes, the desired texture will dictate the boiling time required. Use of softened water (pH about 7.5) or of a 0.5 percent sodium bicarbonate solution (pH 7.5 to 7.9) results in much more rapid tenderization and reduces the cooking time required to about one-third of that required in tap water. The bicarbonate may be added to either the soaking water or the cooking water or both; its use in both soaking and cooking water is most effective. However, the use of sodium bicarbonate results in slightly different taste compared to that obtained in tap water. We have not found the taste objectionable, but if it is, or if sodium bicarbonate is in short supply, then soaking in bicarbonate solution and cooking in tap water may be a preferable method of processing. Also the pH may be raised to 8.0 to 8.5 if faster tenderization is desirable. It is important to note, however, that a high pH will increase the loss of thiamine.

Soaking and boiling also removes about one-third of the oligosaccharides in soybeans, some of which are believed responsible for the production of intestinal gas or flatus. Only a small amount of the protein (1 percent of the Kjeldahl N) is lost during soaking and blanching.

As mentioned earlier, when the tissue of the soybean cotyledon is disrupted or damaged and moisture is present, the characteristic beany or painty off-flavor develops. In University of Illinois tests, drum-dried products were prepared using 0, 25, 50, 75, and 100 percent slightly damaged soybeans (3). Taste panels could easily detect the beany off-flavor when 25 percent slightly damaged soybeans were processed by the Illinois process, although the flavor difference was not pronounced. If hull damage is greater than 15 to 20 percent, blanching before soaking is recommended.

Properly hydrated and blanched soybeans offer great potential for processing into a wide variety of food products. Some of the foods made at the University of Illinois are listed in Table 5. Each category will be discussed briefly.

Category I. Drum-dried Flakes

The drum-dried flakes were made by preparing a smooth slurry of the cooked beans in water and drum-drying the slurry on a double drum drier. If the final product contains other materials, such as fruit or cereals, these are mixed in the soybean slurry and the combination is drum-dried (Fig. 1). The dried flakes may be ground to any fineness desired. These flakes may be used directly, as a weaning food, or they may be mixed into other food such as baked goods to increase the protein content. Mixtures of soybeans and cereals, such as corn or rice, improve the balance of essential amino acids. Cereals are typically low in lysine and adequate in methionine whereas legumes, such as soybeans, are normally the reverse--that is, low in methionine and high in lysine. We have determined the protein efficiency ratio (PER) on several drum-dried soybean-cereal combinations and found that all PER's were between 2.0 and 2.5 (PER for casein = 2.5).

Table 5. Prototype foods made from whole soybeans.

Category I. Dry powders

1. 100% whole soybean
2. Soy-rice (50:50)
3. Soy-corn (50:50) and (2:1)
4. Soy-brown sugar-peanut (50:35:15)
5. Soy-banana (50:50) weaning food

Category II. Canned food products

1. Vegetarian soybean
2. Three bean salad
3. Soy with chicken
4. Soy with pork
5. Soy with lamb
6. Pork with soybeans

Category III. Dairy product analogues

1. Beverage, plain
2. Beverage, chocolate flavored
3. Blend of soy beverage and cottage cheese whey
4. Ice cream, mocha flavor
5. Yogurt

Category IV. Spreads

1. Diet spread, margarine flavor
2. Potato chip dip
3. Peanut butter analogue

Category V. Snack foods

1. Roasted soybean cotyledon
2. Extruded, puffed rice and corn fortified with full-fat soy flour

Soybean-fruit mixtures have potential because the flavor of the fruit is dominant in the dried flakes while the increased protein and calorie content of the soybean is present. A 1:1 soybean:banana flake was prepared in the manner described in Fig. 1 and as described earlier (2). The best product resulted when very ripe bananas were used. This product is very stable and contains a good mixture of the major nutrients--viz. 23 percent protein, 9 percent oil, and 50 percent carbohydrate. It was found to be low in methionine (14) and its PER is below 2, but this deficiency can be corrected by adding maize to the formula as mentioned in a paper by Bressani et al. (4). This product should provide a tasty, nutritious weaning food simply by mixing with boiling water. This also provides a useful method for using very ripe bananas which would otherwise be discarded.

Category II. Home Cooked and Canned Soybeans

The concept for hydration and blanching of whole soybeans offers potential for home utilization of whole soybeans. Recipes for preparation of soybeans for home use have been developed and are available from a number of countries. We believe that the principles mentioned earlier for hydration and blanching of the beans would improve some foods in which the recipes call for procedures that would allow some lipoxygenase activity before blanching or cooking. We also believe that addition of $NaHCO_3$ to the water will result in more tender, and therefore more acceptable, soybeans.

We have used a number of recipes to prepare canned soybeans having a variety of flavors (Table 5). Except for the use of $NaHCO_3$ in the soaking water all of the procedures used are standard for canning beans. The major steps are listed in Fig. 2 and three sauces are given in Table 6. Organoleptic evaluations demonstrated that canned soybeans are highly acceptable; the response of visitors from many countries throughout the world indicate that cooked or canned soybeans should have very wide acceptance, provided they can be cooked to adequate tenderness in a reasonable length of time. Since $NaHCO_3$ is not readily available in most developing countries, the tenderness and cooking time of soybeans are still important obstacles to their acceptance.

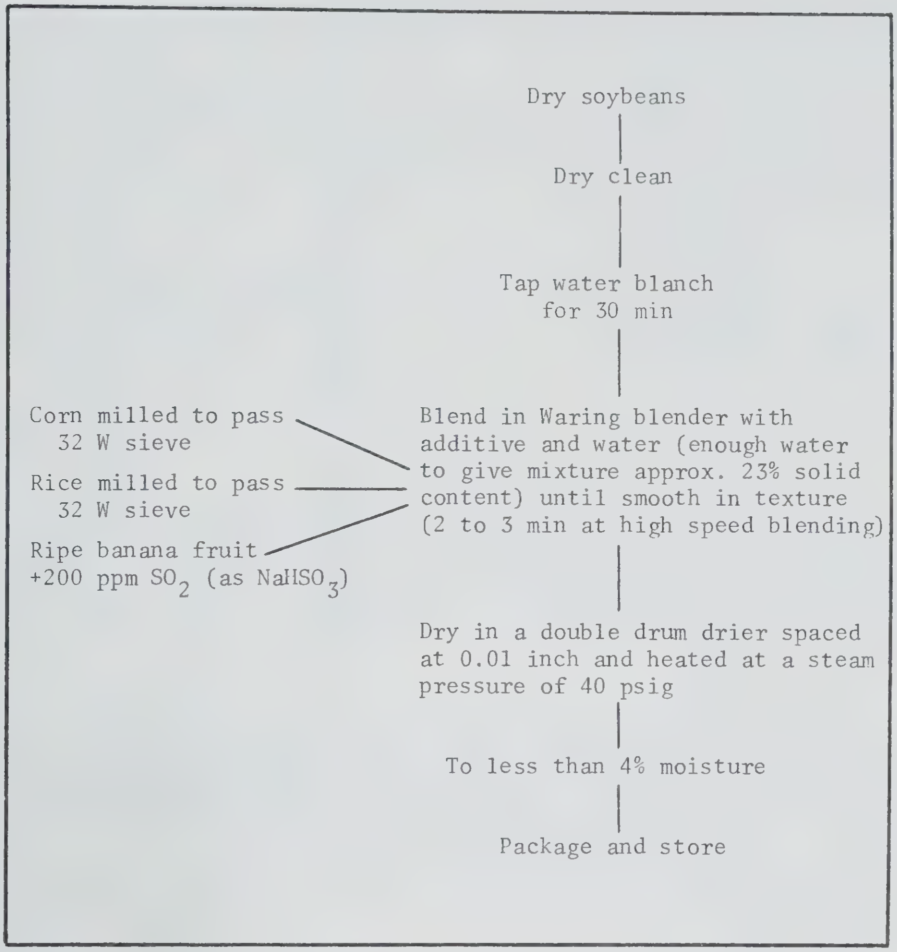


Fig. 1. Preparation of drum-dried soybean flakes (soybean-banana; 50:50 or 60:40, solid basis; whole soybean flake; soybean-rice, 1 to 1; soybean-corn, 1 to 2).

Category III. Soybean Beverages and Beverage Products

A simple process was developed at the University of Illinois which allows the use of blanched soybeans to produce a stable soy beverage with no beany flavor (12). The whole soybean is used and the soy beverage contains as much as 3.5 percent protein (depending on dilution), equivalent to cow's milk and nearly twice that in soymilk currently marketed or in soymilks manufactured by the traditional Oriental process. Essentially 100 percent of the protein and over 95 percent of other constituents are recovered from the bean. The only losses occur during blanching and these losses (primarily carbohydrate) are desirable with respect to reducing flatus. Basically the beverages are prepared by grinding the cooked soybeans with water, adding sucrose and flavoring, homogenizing, and pasteurizing (Fig. 3). A University of Illinois patent covers the preparation of the soybean beverage base.

The major advantages of this process are an excellent mild flavor, no off-flavor, destruction of antinutritional factors, and increased nutritional value relative to most other soybean beverages. The major disadvantage is the necessity of homogenization in order to produce a stable suspension. The beverage base has been used to replace milk in products such as soy ice cream, soy yogurt, custard, and diet margarine, all of which are prepared by conventional methods. Soy beverage base is presently marketed by G.B. Pant University, Pant Nagar, India. The selling price (which allows some profit) is about one-third that of cow's milk.

Dry whole soybeans
↓
Dry clean and inspect
↓
Wash with water
↓
Blanch in 0.5% $NaHCO_3$ for 40 min
↓
Drain and rinse
↓
Remove loose hulls by water flotation
↓
Place in "C" enamel cans
↓
Fill with hot sauce ← Prepare sauce
↓
Exhaust and close
↓
Thermally process for 60 min at 121°C for a No. 1 can
↓
Cool to 40°C
↓
Label and store

Whole soybeans
↓
Dehulling (optional)
↓
Soak in water
↓
Hot water blanch
↓
Drain and rinse
↓
Grind in hammermill
↓
Add water
↓
Add sweetener & flavoring
↓
Homogenize
↓
Pasteurize
↓
Fill

Fig. 2 (left). Preparation of canned soybean products.
Fig. 3 (above). Preparation of a soybean beverage base.

Table 6. Sauce formulations for canned soybean products.

1. Pork and beans

Tomato pulp	80 l
Onion powder	3.0 kg
Garlic powder	200 g
Sugar (brown)	20 kg
Molasses	10 kg
Salt	10 kg
Starch (corn)	800 g
Cayenne pepper	15.2 g
Charzyme	20.0 g
Oil of clove	0.04 ml
Oil of allspice	0.04 ml

Yield sufficient for about 780 No. 1 cans.
Mix all ingredients and heat to boiling.
Fill at 96-100°C.

2. Soybeans with chicken

Use 145 g blanched soybeans plus 28-30 g precooked, diced chicken to fill a No. 1 can. Fill with sauce. Use proportionally larger amounts to fill larger cans.

Tomato pulp (5% sol. solid)	2.06 kg
MSG	22.5 g
Salt	450 g
Curry powder (McCormick)	22.5 g
Ground cayenne pepper (McCormick)	6.0 g
Corn starch	450 g
Water	2.85 l
Chicken broth	9.90 l

Table 6. (continued)

3. Vegetarian soybeans

To fill a No. 1 can use 128 g blanched soybeans, 28 g diced carrots and 14 g cut green beans.

Tomato pulp (5% sol. solids)	4.11 kg
Salt	600 g
MSG	30 g
Curry powder (McCormick)	45 g
Ground cayenne pepper (McCormick)	45 g
HVP (Magge 312)	300 g
Minced onion (Basic, dry)	150 g
Garlic powder (Stange #41019)	15 g
Water	25.5 l

Category IV. Spreads

Spreads, or intermediate moisture foods, constitute another group of soy food products. An excellent diet margarine was prepared following conventional methods but using soy beverage instead of milk solids. A very acceptable potato chip dip can be prepared simply by changing the flavorings used. Roasted soybean cotyledons plus added soybean oil can be processed, using a colloid mill, into a "soybean butter" that resembles peanut butter in character and flavor.

Category V. Snack Foods

Tasty snacks may provide an avenue for introducing soybean foods to people who normally would resist trying any unfamiliar food. Soybeans can be roasted to make a dry nut similar to peanuts. First the blanched soybeans should be dehulled, using a disc (buhr) mill or similar mill. At home, dehulling can be done by rubbing small handfuls between the hands. The mixture is rinsed with water to remove the hulls and fines. After draining, the cotyledons are deep-fried in oil at about 190°C for two and a half minutes. They may be roasted at home in a frying pan with a little oil but the roasting time will be longer. If the hulls are left on, the roasting time is longer. Salt or other flavorings should be added while the beans are still hot.

Puffed snack foods have also been prepared using a Wenger extruder. The feed flour contains about 20 percent full fat soy flour and 80 percent corn or rice flour. After addition of oil and flavoring (as is usually done to this type of snack) the protein content is at least 3 g/100 calories. (The recommended daily protein allowance in the United States is 2.3 g/100 calories.)

Many others have reported the use of whole soybeans for the preparation of high protein foods. For example, Bressani et al. reported the preparation and nutritional evaluation of numerous soybean:maize mixtures for possible use in tortillas (3, 4). These mixtures were prepared as shown in Fig. 4. As shown in Table 7, they found that the best ratio of soybean:maize was 28:72. This mixture gave a PER of 2.54 whereas 100 percent maize resulted in a PER of 0.69 (casein = 2.87). Tortillas were prepared from a mixture of maize: whole soybeans (85:15) prepared in a manner similar to that shown in Fig. 4 except that the dough (not the flour) was used directly to prepare the tortillas. The tortillas were reported to have physical and organoleptic characteristics that were very similar to those for tortillas made from maize. However, the protein content was increased from 10 to 14 percent and the PER increased from 0.95 to 1.72. (Rats fed a diet containing 9 percent protein.)

Another interesting soybean:corn combination is "Soy-Ogi" which was developed by the Federal Institute for Industrial Research, Oshodi (FIIRO), in Nigeria (17). This product is produced by a small-scale production facility in FIIRO and test marketing began in July 1974. Preparation of Soy-Ogi begins by steeping whole corn in water for 24 h. The corn is wet-milled and placed in a fermentation vat. Whole soybeans are dehulled, steamed, ground, and added to the same fermentation vat. The ratio of dry soybean and dry corn is 3:7. The mixture is allowed to ferment, using the natural flora developed during the corn steep, and in a manner similar to that used in the preparation of Ogi, a staple Nigerian "pap" used for feeding children. After fermentation, the slurry is pasteurized and spray dried. The protein content of the powder is about 20 percent. As reported by Bressani, and as we have noted in

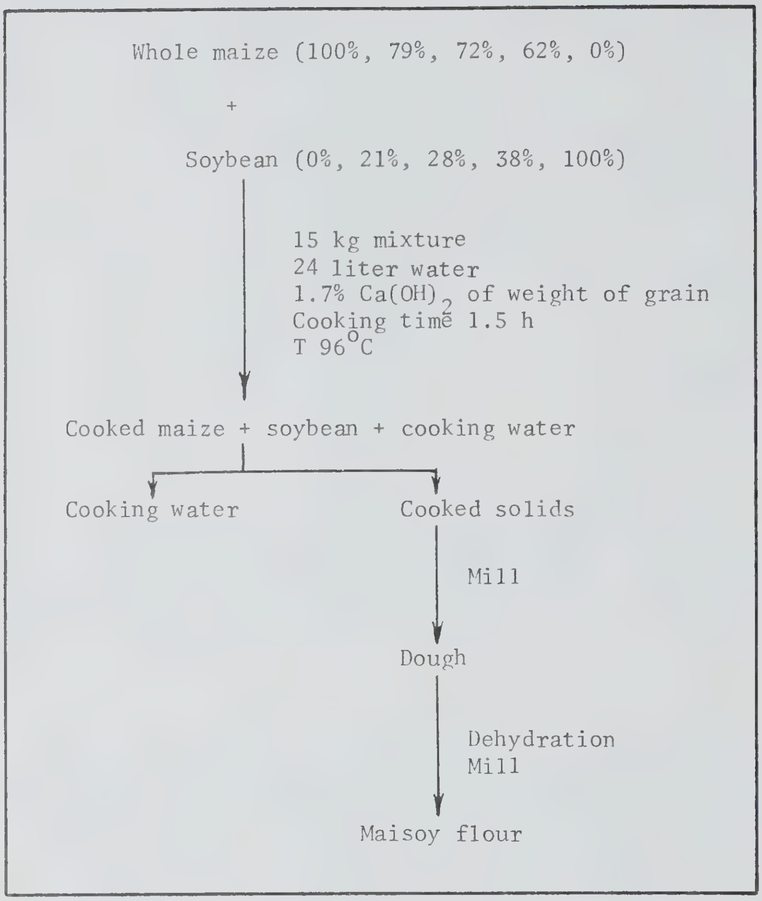


Fig. 4. Processing of mixtures of maize and soybeans. (From Bressani, et al., J. Food Sci. 39:577.)

Table 7. Protein and fat content and protein value of the different maize-soybean preparations.[a/]

Mixture Maize (%)	Mixture Soybean (%)	Content of Protein (%)	Content of Fat (%)	Average weight gain (g)[b/]	Protein efficiency ratio (PER)
100	0	9.9	4.5	12	0.69
79	21	16.9	8.9	81	2.08
72	28	17.6	10.3	91	2.54
62	38	18.1	11.3	99	2.37
0	100	40.0	25.6	101	2.03
Casein		--	--	120	2.87

a/ All diets were calculated to contain 9 percent protein

b/ Average initial weight: 47 g.

Source: Bressani et al., J. Food Sci. 39:577 (1974).

our own work at the University of Illinois, the 3:7 ratio of soy:corn will yield an optimum balance of amino acids. An adult version of Soy-Ogi, which contains 12 percent protein, was also developed. Both products are prepared by mixing with water and bringing to a boil. Different amounts of water, or addition of other foods, may be used to prepare products with different consistencies or flavors.

Spata et al. recently reported the development of a soybean dal (15). (Dals are cracked pulses and are a staple in many Indian diets.) Soybeans were dehulled, cracked, and the cotyledons and hulls separated. The cracked cotyledons were dropped directly into boiling water, blanched, and dried in the sun or with a drier. Estimated cost was within the range of locally used dals and organoleptic evaluation demonstrated good acceptability.

These examples illustrate the wide variety of tasty and nutritious foods that can be manufactured from a single starting material--the cooked, whole soybean. We believe they demonstrate a great potential for this versatile food ingredient and we believe that these and other soybean products can be adapted to fit the taste and texture preferences of people throughout the world.

REFERENCES

1. Anonymous. 1972. Good tasting soy products. Food Processing 33(7):F7-F10.
2. Bird, D., L.S. Wei, L.K. Ferrier, and A.I. Nelson. 1973. Weaning food prepared from whole soybeans and bananas by drum drying. Presented at the meeting on nutritional aspects of common beans and other legume seeds as animal and human food, Ribeirao Preto, Brazil, November 1973.
3. Bressani, R. 1974. Soybean as human food. In Proceedings, Workshop on Soybeans for Tropical and Subtropical Conditions. University of Puerto Rico, Mayaguez.
4. Bressani, R., B. Murillo, and L.G. Elias. 1974. Whole soybeans as a means of increasing protein and calories in maize-based diets. J. Food Sci. 39:577-579.
5. Cravens, W.W., and E. Sipes. 1958. Page 372 in W.W. Cravens and E. Sipes, Processed plant protein foodstuffs. Academic Press Inc., New York.
6. Danbert, B.F. 1950. Page 173 in B.F. Danbert, Soybean and soybean products. Interscience Publisher Inc., New York.
7. Food and Agriculture Organization of the United Nations. 1968. Amino acid content of foods. FAO, Rome.
8. Iriarte, B.J.R., and R.H. Barnes. 1966. The effect of overheating on certain nutritional properties of the protein of soybeans. J. Food Tech. 20:131-134.
9. Lawrie, R.A. 1970. Proteins as human food. Avi Publishing Co., Westport, Conn.
10. Meyer, E.W. 1967. Soy protein concentrates and isolates. Pages 142-155 in International Conference on Soybean Protein Foods. Peoria, Ill. (1967).
11. Nelson, A.I., L.S. Wei, and M.P. Steinberg. 1971. Food products from whole soybeans. Soybean Dig. Jan. 1971.
12. Nelson, A.I., M.P. Steinberg, and L.S. Wei. Soy beverage base. Patent granted in France and Belgium. Patent pending in other countries.
13. Rodda, E.D., M.P. Steinberg, and L.S. Wei. 1973. Soybean damage detection and evaluation for food use. Trans. A.S.A.E. 16(2):365-366.
14. Shemer, M., L.S. Wei, and E.G. Perkins. 1973. Nutritional and chemical studies of three processed soybean foods. J. Food Sci. 38:112-115.
15. Spata, J.A., A.I. Nelson, and S. Singh. 1974. Developing a soybean dal for India and other countries. World Crops, March/April 1974, pp. 82-84.
16. Wei, L.S., R. Berra, A.I. Nelson, and M.P. Steinberg. 1973. Canned pork and beans: a nutritious and tasty new product. Illinois Research, Spring 1973, pp. 6-7.
17. Further information may be obtained from: Director of Research, Federal Institute for Industrial Research, P.M.B. 1023, Ikeja, Lagos State, Nigeria.

DISCUSSION

W. PLARRE: Did you use black soybeans for processing and did you find an influence on the color of the flour?

L.K. FERRIER: Not to any extent. I would expect the flours to have a greyish color if black soybean hulls were included.

M. VON OPPEN: Are there differences in varieties as far as processing is concerned?

FERRIER: For practical purposes, no. There are some differences in color if, for example, one uses a black-hulled variety for preparation of flours.

S. MOUTIA: How much soybean milk does one get from 1 ton of beans?

FERRIER: We got 1:10 at 4 percent protein in milk.

MOUTIA: What is the strength of the bicarbonate solution used for tenderizing?

FERRIER: We used a 0.5 percent solution of bicarbonate. The quality of the soaking water affects the tenderness. Of all the products used, the bicarbonate has been found to be the best.

MOUTIA: What is the position of soybean products in diabetes, and in cholesterol patients?

FERRIER: It is not possible for me to answer the question.

E. HERATH: How do you avoid the beany flavor in soy beverage or soy milk?

FERRIER: The beany flavor is prevented by boiling the whole beans before further processing. This inactivates the enzymes that cause the formation of the beany flavor.

Production of Soybean in Egypt

A. Abdel-Aziz, A. Nassib, and S. Mahmoud

The efforts to introduce and popularize soybean as a crop in the Egyptian agriculture have aimed at:

1. Making up for the deficit in the national production of cotton seed, which is the main supplier of food oil and animal feed meal. Both products meet only one-third of the local demand of each commodity.
2. Providing the country's growing poultry industry with a rich source of protein.

The cultivated area in Egypt is about 6 million acres (2.5 percent of the total area) which is equivalent to 11 million acres through double- and multiple-cropping systems. In addition, 900,000 acres of reclaimed desert land are in various stages of agricultural development and settlement. Excepting the western coastal strip on the Mediterranean (which receives annual winter precipitation of 100 to 200 mm) and some sparse oases in the western desert dependent on spring water and wells, the cultivated land, mainly in the delta and the valley, is canal-irrigated fed from river Nile. Hence, the Egyptian agriculture is an intensive cropping system in which the field crops are cotton, cereals, food legumes, onions, oil crops, sugar cane and Egyptian clover. On the other hand Egypt's rapidly increasing population and the consequently growing demand for these traditional crops, either for domestic consumption or exportation, leave no room for expansion of soybean. Any area under this crop will be at the expense of cotton, corn, rice, or sugar cane.

The following channels can be tried to clear the way for growing more soybean:

1. Incentives to the farmers in providing inputs and better prices for their produce so as to compete with other summer crops. In this regard, the policy is drawn and supervised by the Soybean Council which is an independent organ involving representatives of research, production, agricultural extension, and poultry industry.
2. Investigating the possibility of interplanting soybean with other summer crops--for example, corn.
3. Evolving early- and late-maturing varieties to cope with different situations in field crop rotation.
4. Investigating the possibility of allocating more acreage of reclaimed land to this crop.

In the 1974 season about 5,000 acres, mostly in the delta and middle Egypt, were grown to soybean with an average production of 500 kg/acre and a range of 200 to 1,250 kg/acre.

VARIETIES ADAPTATION

Work on soybean was initiated in the thirties but introduction and testing of varieties on a large scale did not occur until 1963. The first batch from the United States consisted of 17 varieties belonging to maturity groups IV, V, VI, VII, VIII. Later, Clark and Hampton proved to be adapted under our conditions, and were released for production as early- (120 days) and late- (170 days) maturing varieties.

A. ABDEL-AZIZ, Chief of Research; A. NASSIB, Senior Researcher; S. MAHMOUD; Researcher: Legume Research, Field Crop Research Institute, Ministry of Agriculture, Orman Giza, Egypt.

Egypt is located 22^{o} to $31^{o}30'$ N latitude and has a long, dry summer season. April through October, the maximum temperature ranges from 22^{o} to $39^{o}C$ and the minimum range is 6^{o} to $22^{o}C$. Under these climatic conditions, introducing and testing of new varieties expanded, covering almost the nine maturity groups. Meanwhile, selection was practised within some of the promising varieties for more adapted lines. Table 1 presents the seed yield of 6 selected lines and 9 introduced varieties tested at five locations in the 1973 season. The statistical analysis showed significant differences among varieties at one location only. On the average, Bragg, Lee, Hampton St2, Clark, and N.C. Hampton St1 seemed to outyield the 10 other varieties.

The International Soybean Program (INTSOY) variety evaluation trial at Bahteem in 1973 (Table 2) indicated that Williams (group III) at an average of 524.3 kg/acre significantly exceeded 12 varieties within maturity group range IV to IX. The yield of seven other varieties in the range II to IV was not significantly lower compared with Williams. The trend of these results is in agreement with Ford variety trial at Sakha in 1973 (Table 3), where the six top- yielding varieties are listed in maturity groups II, IV, V, VI, and VII, and six lower varieties are within groups V, VI, VII, and VIII.

Apparently the general tendency of earlier group varieties toward higher adaptability as compared to the late groups in both trials may be attributed to the fact that planting date was late in July. Thus, the growing season was too short to show the yield potential of the latter groups.

INTERCROPPING

Studies on soybean interplanting with corn were aimed at increasing the acreage of soybean under our intensive cropping system and simultaneously maintaining the production of the staple crop--corn--at a reasonable level to meet the local demand. Either both crops are sown on the same date or corn is delayed 20 or 35 days after sowing. Corn and soybeans are interplanted alternately on ridges 70 cm apart. The results are not consistent and differ from one location to another for both crops. Generally, as corn planting is delayed soybean yield increases and may occasionally reach the level of solid crop. Varietal response of soybean yield to interplanting does exist. The yield of interplanted corn is comparable to solid crop when planted on the same date as soybean. However, the production declines as sowing dates of corn are retarded.

CULTURAL PRACTICES

Soybean is a new crop to Egyptian farmers. Future yields from soybeans, however, are likely to increase with better varieties, improved agronomic practices, and as farmers gain experience in their production.

Studies have been undertaken to determine the best agronomic practices that will contribute to improvement in the yield of soybean. The factors studied are: date and rate of seeding, planting methods, fertilization, and optimum number of irrigations. Their reflection on seed quality and the incidence of pests and diseases is also considered. The data presented here are based on collective investigations designed and analyzed statistically.

Planting Date

A pilot experiment for studying the optimum planting date, using the two varieties Hampton (160 to 180 days) and White Biloxi (180 to 190 days), was conducted. Four planting dates at one-month intervals beginning April 15 were studied. The results indicated that early plantings during April and May out-yielded the late plantings of June and July for the two varieties studied. The average yield of seeds/acre was 651, 627, 519, and 220 kg for the four planting dates respectively.

In another experiment including the early variety Clark (110 to 120 days), four planting dates at 20-day intervals beginning April 15 showed the same trend. The yield/acre was 435, 415, 360, and 209 for the planting dates April 15, May 5, May 25 and June 15 respectively.

Table 1. Results of variety trials at five locations, Egypt, 1973.

Variety	Maturity group	Yield (kg/acre) Sakha	Gemmiza	Bahteem	Seds	Mallawi	Average
Latitude		$31^{o}.15$	$30^{o}.50$	30^{o}	29^{o}	28^{o}	
Bragg	VII	1,024.3	577.1	719.4	801.1	789.4	782.3
Lee	VI	1,026.7	510.4	440.2	880.8	983.9	768.4
Hampton St2	VIII	1,144.9	832.2	570.9	344.2	904.2	759.3
Clark	IV	1,204.0	831.2	886.7	266.4	593.1	756.3
N.C. Hamp. St1	VIII	1,473.1	690.3	567.8	204.2	803.1	747.7
Semmes	VII	966.1	564.9	727.2	383.1	878.9	704.0
Hill	V	1,358.0	127.4	763.0	705.8	529.9	696.8
Hale 7 St1	V	1,132.4	249.3	641.2	663.1	701.9	677.6
Davis	.VI	886.7	270.3	585.7	789.4	705.8	647.6
Hood St2	VI	944.2	487.1	533.4	548.3	717.5	628.1
Jackson St2	VII	724.1	485.8	414.6	577.5	872.1	614.8
Rebel St2	VIII	876.6	250.1	622.2	429.7	770.8	591.3
Dare	V	217.8	635.8	586.4	766.1	740.8	589.4
Harosoy	II	804.2	334.2	619.1	140.0	840.0	547.0
Corsoy	II	692.2	84.6	594.2	291.7	837.1	500.0
LSD		--	444.1^{+}	--	--	--	--

Table 2. Results of International Soybean Program (INTSOY) variety trial at Bahteem, Egypt, 1973.

Variety	Maturity group	Days to maturity[a/]	Height at maturity (cm)	Yield (kg/acre)	100-seed wt/gm	Percentage oil	Percentage protein
Williams	III	90	47	524.3	12.0	20.2	47.4
Picket 71	VI	90	67	476.0	8.3	17.1	37.6
Harosoy 63	II	90	48	474.6	12.6	20.7	47.1
Clark	IV	90	41	470.4	11.7	18.2	50.8
Clark 63	IV	90	52	469.0	12.3	21.9	49.6
Adelphia	III	90	48	437.5	10.4	20.1	48.6
Lee 68	VI	90	58	433.3	7.4	18.3	36.8
Dare	V	90	65	407.4	7.1	19.8	35.6
Semmes	VII	90	60	383.6	7.4	16.2	38.3
Hamp. 266A	VIII	90	71	345.8	9.4	19.8	38.3
Hill	V	90	66	325.8	7.3	18.6	35.6
Hampton	VIII	90	66	289.9	10.1	19.5	51.0
Bonus	IV	90	44	289.8	11.3	21.7	49.6
Bragg	VII	90	72	267.4	7.4	16.3	34.8
Rebel	VIII	90	64	263.9	8.5	17.9	54.5
Davis	VI	90	62	256.2	7.8	17.8	37.3
Lee	VI	90	69	221.9	7.8	19.9	50.2
Hutton	VIII	90	55	209.3	8.8	20.0	35.8
Jupiter	IX	115	101	196.0	10.7	19.5	38.6
Imp. pelican	VIII	105	84	193.9	8.7	20.5	37.2
LSD		--	--	118.3^{+}	--	--	--

a/ Sowing date = July 24, 1973.

Table 3. Results of Ford variety trial at Sakha, Egypt, 1973.

Variety[a/]	Maturity group	Yield (kg/acre)	Variety	Maturity group	Yield (kg/acre)
Clark	IV	534.5	Hampton	VIII	367.6
Clark 63	IV	511.2	Bossier	VII	318.6
Harosoy	II	498.9	Dare	V	317.5
Lee 68	VI	409.0	Hamp. 266A	VIII	310.8
Bragg	VII	389.6	Semmes	VII	196.1
Pickett	VI	372.9	Davis	VI	189.0

a/ Sowing date = July 27, 1973.

In 1973 a new series of experiments was conducted in four locations representing lower and middle Egypt, using three soybean varieties representing the different maturity classes. The varieties used were Clark (110 to 120 days), Davis (130 to 140 days) and Hampton (160 to 180 days). Ten planting dates at 15-day intervals beginning March 15 were investigated and results are presented in Table 4. Early sowings from March 15 to May 15 gave the higher yields/acre, while lower yields were obtained from the late sowings during July and August. The results of these experiments are quite in agreement with previous studies.

Spacing and Sowing Methods

In Egypt two methods of sowing--hirati and afir--are commonly practiced with many seed crops. In the hirati method the soil is watered preplanting and after a few days, depending on soil moisture, the seeds are planted in the wet soil 3 to 5 cm deep and compactly covered. In the afir method the soil is prepared and left dry, the seed is planted, and the field is watered immediately after seeding.

Soybean is commonly planted on ridges 60 cm apart and the seeds are spaced in hills 10 to 15 cm apart. The two sowing methods with different hill spacing were studied, using the varieties Clark and Hampton over the three years 1968-1970. The results, based on the average of the three years, are shown in Table 5. The hirati method significantly out-yielded the afir method and this may be attributed to soybean sensitivity to overwatering The results also indicate that 5 to 10 cm between hills produced higher yield of seed/acre than the 15 to 20 cm spacing.

In another experiment the effect of plant density on yield of the variety Hampton was studied. Two hill spacings (10 and 20 cm) and three treatments for number of plants per hill (1, 2, and 3 plants) were investigated. The results, based on the average of three years, are shown in Table 6 and indicate that planting in hills 10 cm apart with 3 seeds/hill gave the highest yield/acre.

Irrigation

Six experiments were conducted over the three years 1967-1969 at Seds and Mallawi in middle Egypt to determine the optimum number of irrigations for soybean. The variety Hampton was used and four, five, and six waterings at 20-, 15-, and 10-day intervals respectively were investigated. The results, shown in Table 7, indicated no significant differences among the different treatments.

In the current season, new experiments are in progress to study the proper timing of irrigation in the different planting dates of the varieties Clark and Hampton.

Fertilization

Very little experimental work on fertilizing soybeans has been done in Egypt. However, in the current season, considerable experimental work has been initiated especially with the amount and time of application of nitrogen and P_2O_5.

On the average the soybean fields are fertilized at the rate of 30 to 40 kg N and 30 kg P_2O_5 per acre.

Table 4. Effect of planting date on seed yield (kg/acre) of three soybean varieties at four locations in Egypt, 1973 season.

Sowing date	Sakha			Bahteem			Seds			Mallawi			Mean
	Clark	Davis	Hampton	Clark	Davis	Hampton	Clark	Davis	Hampton	Clark	Davis	Hampton	
March 15	171.6	952.0	1,619.4	919.4	989.9	535.5	186.1	573.1	1,023.5	758.4	745.4	515.1	749.1
April 1	1,149.2	821.4	1,523.1	1,051.2	708.8	802.7	350.0	965.1	1,031.9	783.4	771.2	1,163.8	926.8
April 15	1,237.9	864.5	1,510.9	891.9	513.3	917.6	460.0	986,4	1,081.2	796.3	797.0	884.4	886.8
May 1	1,359.8	982.4	1,474.2	885.5	575.2	716.9	474.0	748.4	584.2	739.7	557.7	744.4	520.2
May 15	1,250.1	1,050.6	1,222.7	975.4	494.7	594.4	514.8	673.5	541.3	899.5	604.3	774.7	799.6
June 1	982.4	1,083.9	1,115.9	859.3	646.9	553.6	629.1	695.6	356.1	329.0	443.3	436.9	677.7
June 15	933.9	1,163.8	1,204.6	875.0	928.7	669.7	718.1	552.4	355.5	534.9	647.5	741.4	777.1
July 1	1,029.0	1,111.9	972.4	656.9	428.8	813.2	230.4	305.7	269.8	362.3	369.3	447.4	583.1
July 15	689.5	915.8	562.9	474.8	666.2	780.5							
August 1	491.2	390.3	195.4	400.8	536.7	522.7							

Table 5. Effect of afir and hirati sowing methods and seed spacing on yield of Clark and Hampton varieties of soybean.

Spacing (cm)	Yield (kg/acre) Clark Afir	Clark Hirati	Clark Mean	Hampton Afir	Hampton Hirati	Hampton Mean	Mean
5	297	360	329	583	664	623	476
10	290	435	362	558	666	612	487
15	258	315	287	528	698	613	450
20	311	339	325	502	675	588	459
Mean	289	363		543	676		
Afir:	416			Clark:	326		
Hirati:	515			Hampton:	609		

Table 6. Effect of plant density on yield of soybean variety Hampton.

Hill spacing (cm)	Yield (kg/acre) Number of plants per hill 1	2	3	Mean
10	786 (70)[a/]	829 (140)	850 (210)	822
20	687 (35)	840 (70)	786 (105)	771
Mean	736	827	818	

a/ Figures in parentheses represent number of plants per acre in thousands.

Table 7. Effect of number of irrigations on seed yield of soybean at two locations.

Irrigations Number	Interval (days)	Mean yield (kg/acre) Seds	Mallawi	Mean
4	20	524	802	663
5	15	481	836	658
6	10	521	801	661
Mean		509	813	

Rhizobium Inoculation

It is commonly accepted that effective inoculation increases the yield of seeds and their protein content. Unfortunately, under our conditions very few nodules are usually formed despite inoculum application. This may be due to the ineffectiveness of the local commercial inoculant material.

A program was initiated in the current season, with the cooperation of the Microbiology Section, to study the problem of poor nodulation in soybeans. Any assistance that might be provided by INTSOY in this line of research would be appreciated.

Insects and Diseases

Most insects that attack the soybean plant can be controlled by timely application of proper insecticides.

The most important insects in soybean plantations in Egypt are cotton leaf worm (*Spodoptera littoralis* Boisd) and the red spider (*Tetrarychus telarius* L.).

So far diseases have not been a problem to soybean in Egypt. However, the most prevalant diseases are root rot (*Rhizoctonia solani*, *Fusarium solani*, *Sclerotium bataticola*, *S. rolfsii*, *Pythium* sp.), wilt (*Fusarium oxysporum*), and leaf spot (*Alternaria* sp.)

FUTURE PROGRAM

Plans for future soybean research in Egypt include continued testing of diverse materials and intensified studies of cultural practices, especially fertilization, water requirement, weed control, and intercropping.

DISCUSSION

M. VON OPPEN: In what form is Egypt going to utilize the rapidly increasing production of soybeans?

A. ABDEL-AZIZ: (1) Making up for the deficit in the national production of cotton seed, which is the main supplier of food oil and animal feed meal. (2) Providing the growing poultry industry in the country with a rich source of protein.

R.K. JANA: How much water was applied in each application of irrigation? If amount of water is not fixed, that may be the reason why no significant difference in yield was obtained in 4, 5, and 6 irrigation treatments.

ABDEL-AZIZ: Perhaps this may be the reason for obtaining nonsignificant results and this may be clarified in the future work through cooperation with the people responsible for water requirement research in our country.

Introduction of Soybeans in Ethiopia

O. Hammar and L.G. Haraldson

Soybeans were tentatively tried in Ethiopia in the 1950s. A growers' manual was even published in Amharic and instructions on how to use the "foreign pea," as the soybeans were called at that time in Ethiopia, were also included.

Yields were rather discouraging though. At the research station in Debre Zeit, belonging to the agricultural college, average yields of 1,090 kg/ha were obtained in the years 1958-1963. Jimma Agricultural College had one trial in 1956. Top yielder was Acadian with 1,100 kg/ha.

The efforts were then discontinued for some time. But in 1967-1970 the Chilalo Agricultural Development Unit (CADU) tried some varieties from both America and Germany. A yield of 1,600 kg/ha was obtained from Amsoy in 1970 at 2,100 m altitude. This was considered promising and thus CADU and the Ethiopian Nutrition Institute (ENI) launched a joint introduction program. The aim of this program was two-fold: (1) to replace the soybean flour imported by ENI for use in the children's food product Faffa with locally produced soybean products, and (2) to introduce soybeans in the diet of the peasant farmers because of its high nutritional value.

Identification of Suitable Varieties

In 1971 varieties were gathered from various parts of the world. B. Radley, then at Makarere University of Uganda, supplied a nursery including 112 entries. Another nursery from the Food and Agriculture Organization, with 63 entries, was also planted. In addition, entries from West Africa, the United States, and Indonesia were tried. The next year, 91 entries from East Africa, the United States, and Japan were tried at Jimma Research Station and a lesser number from East Africa at Kulumsa (CADU). The International Soybean Program (INTSOY) provided a set of 14 varieties that were grown at three locations.

Through these trials it was possible to identify some promising late-maturing varieties and some promising early ones. The late-maturing group consisted of Hardee, Kenrich, and Madarin. The early-maturing group included Clark 63, Calland, and Amsoy. Coker 240, which takes an intermediary position, does well also. In trials, Coker 240 has yielded 2,820 kg/ha, Clark 63 yielded 2,790 kg/ha, and Mandarin 2,990 kg/ha. The highest yield recorded so far is from Hardee which twice has produced more than 4,000 kg/ha. Basis for selection has been yield capacity and number of pods per plant.

Identification of Suitable Areas

In 1971 soybeans were tested at six locations. Since then the number of localities where replicated trials have been grown has increased to 22. The altitude of these locations ranges from 300 to 2,100 m. Soil types range from Black Cotton Soil and Red Lateritic soils to dry silty soils. The highest yields seem to be achieved at altitudes between 1,300 and 1,700 m where there is a good combination of temperature and rainfall. Good yields have sometimes been received at 1,900 m altitude, while no soybean has done really well above 2,000 m.

The tested set obviously is not fitted for the high temperatures at low altitudes as the yields have been low, even when irrigation has been applied. As for soil types, it seems that soybeans do best in clayey soils, probably because of the water capacity of these soils.

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Cultural Practices

Inoculation has had no significant effect on yield. Fertilization with 40 to 50 kg/ha of P_2O_5 has given very good results where the soil phosphorus is low. Population trials have indicated that a seed rate of 70 kg/ha should be used. A spacing of 40 cm between rows seems to be suitable and this allows weeding to be done both by hand and by using the local plough with two oxen.

In recent years downy mildew, purple stain, and viruses have been observed, but the only real damage to the crop so far has been done by cutworms and weeds. Threshing has been done, on large-scale production, by running a tractor over heaps of harvested beans.

Multiplication

Seeds of Clark 63, Amsoy, Coker 102, and Calland were imported directly from the United States by ENI in 1972 and were grown under contract by local farmers on 64 ha. Yields ranged from 1,180 kg/ha to 370 kg/ha. The main problem was late weeding and negligence in applying the recommended fertilizer. The following year the same varieties plus Habaron Mandarin, and Coker 102 were multiplied. This year Clark 63, Calland, Coker 102, Hardee, Mandarin, and Coker 240 were grown on 60 ha, all contracted by ENI.

Introduction to Farmers

This year a pilot study on how to introduce soybeans to the local farming population has been started by CADU and ENI in corporation. ENI is supplying seed to the CADU agricultural extension agent in a soybean area with the idea that he and the farmer should learn to master the crop with the help of the "Growers Manual" which is handed out. Simultaneously, the CADU women's extension agents will be teaching the farmers' wives how to prepare soybeans and fit them into the local diet and food habits. Before the area was selected, ENI made a nutrition survey to establish whether the population was using the kinds of food into which soybeans could be included.

ENI has also developed a number of soybean recipes for use in the extension work. These recipes are available to interested parties during this conference.

Industrialized Soy Processing

In Ethiopia, ENI's Supplementary Food Program is the only big user of soybeans. Due to lack of processing machinery we are still importing soy flour from the United States, but we believe that we will be self-sufficient in 1976.

Home Preparation of Soybeans in Ethiopia

B.G. Hiwot

Work on soybeans in the experimental kitchen of the Ethiopian Nutrition Institute started some five years ago with defatted soy flour. This was tried out in the traditional sauces and was quite successful.

In February 1972, the unprocessed beans were sent to the institute by United Nations Children's Fund (UNICEF) to be made into the different traditional dishes. Some recipes were developed, but cooking the whole beans presented a problem.

The experimentation continued with soybeans grown in Ethiopia. The variety Clark 63 was used in all our trials, which were conducted in the following manner:

1. The beans were first processed in three different ways.

    a. Plain soybean flour was made by cleaning the beans (removing sticks, stones, leaves, and broken beans), splitting to dehull them, and grinding them into flour.

    b. Roasted soybean flour was made by roasting the clean beans, splitting them to remove the hulls, and grinding the roasted, split beans into flour.

    c. Blanched soybean flour was made by boiling the cleaned beans for 10 minutes, air-drying them, splitting them to remove the hulls, and grinding them into flour.

2. Each of the three kinds of soybean flour was added to the main ingredients of traditional dishes in eight different proportions, i.e. 5, 10, 15, 20, 25, 30, 50, and 100 percent.

3. The prepared dishes, with soybeans substituting for the main ingredients in part or in whole, were then served, with the reference dish (no soybeans added), and evaluated for acceptability by a test panel.

Rating Method Used

The test panel consisted of 10 workers of the Institute who customarily ate traditional foods in their homes and who were experienced in evaluating foods from being panelists for the last 5 years.

The taste, odor, color, and texture of each prepared food was evaluated by each panelist and rated as very good, good, average, bad, very bad, or inedible. A food that had a combination of the first three ratings for the four properties was rated as acceptable, whereas if it had any of the last three ratings for any one property it was rated as unacceptable.

Some traditional foods that were tested were:

1. Injera--a fermented, flat, pancake-like bread used by almost all highland Ethiopians. To make injera, soybeans were mixed with four different cereals, namely, teff (*Eragrostis tef*), barley, sorghum, and corn.

    Results showed that the products were acceptable when roasted soybean flour was used: 20 percent soybeans could be added successfully to teff, 5 percent soybeans could be added successfully to sorghum, and 5 percent soybeans could be added successfully to barley. Soybeans with corn could not be made into acceptable injera.

2. Wots and allichas--sauces served with injera and usually made from meats, fish, legumes, eggs, vegetables, and so on. Soybeans were mixed with two different legumes to make wots and allichas.

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Results showed that the products were acceptable when roasted soybean flour was used: 100 percent roasted soybean flour could be made into highly acceptable wot or allicha, or it could be combined in any proportion to pea flour, split peas, or split lentils for this purpose.

3. Kitta (unleavened bread) is very commonly used in both the highlands and the lowlands of Ethiopia. Three cereals, namely, wheat, barley, and sorghum, and "ensete" (false banana) were combined with soybeans and tried as kitta.

   Results showed that blanched soybean flour worked well with the cereals, whereas roasted soybean flour gave a good result with the ensete. Soybeans could be added successfully as follows: 15 percent to wheat, 15 percent to barley, 10 percent to sorghum, and 20 percent to ensete.

4. Dabbo--the traditional leavened bread usually made of wheat. Soybeans were mixed in varying proportions with wheat flour to make dabbo.

   Results showed that blanched soybean flour gave excellent results in the wheat dabbo. Roasted soybean flour also gave a little darker, but still a highly acceptable, product. As much as 30 percent soybeans could be added to wheat in making dabbo.

5. Dabo kolo is a snack food and is commonly known as "the traveler's food" because of its keeping quality. Soybeans were mixed in different proportions with wheat to make this snack. Results showed that either plain or blanched soybean flour worked well for this product at 9 percent.

6. Porridge, which is frequently used in the lowlands and for special occasions in the highlands, was tried with three different cereals namely, barley, corn, and sorghum.

   Results showed that blanched soybean flour gave acceptable results in porridges, and 20 percent soybeans could be added successfully to barley and corn. Soybeans with sorghum did not give acceptable porridge.

Experiences with Soybeans

The recipes already developed have been found to be highly acceptable by our test panel, other staff of the institute, and visitors.

Whole soybeans, with instructions on how to process and cook them, were given to an orphanage where they were prepared as wot and were served at four meals every week for a period of about 3 months. They were found to be as acceptable as the conventional wots to the children and the kitchen staff. There was a minor problem with the local miller who complained that they were not easy to grind, but he continued to grind the soybeans whenever they were brought to him.

There is a plan to introduce the beans for use at village level in collaboration with Chilalo Agricultural Development Unit (CADU). The village of Arata has been selected as the pilot project area. The food habits, dietary intake, and nutritional status of the population in the area have already been assessed. The next step is to have the women extension agents teach the women in the village how to prepare soybeans in their homes. At the same time, the men extension agents will be teaching the farmers how to grow the beans. Experiences from this pilot project will be used for further introduction of soybeans at village level.

The Ethiopian Nutrition Institute is interested in soybeans as a food that is rich in calories and protein, to be used for local consumption. There is an obvious deficit in calorie and protein intake in a large portion of the population. Soybeans can contribute toward correcting this situation.

The ENI also uses soybeans in two of the products that it makes: Faffa, a weaning food, and SWF, an enriched wheat flour. Both products have been used in famine relief activities. The quantity of Faffa and SWF sold in the past two years and the expected sales figures for 1975 are shown below.

Product	Sales (tons)		
	1973	1974	1975
FAFFA	700	800	1,000
SWF	1,000	2,000	2,600

The Institute is, therefore, also interested in processing its own soybeans to be used in these products.

Soya Bean in Ghana

H. Mercer-Quarshie and
G.F. Nsowah

Ghana lies between latitude 5^{O}N and 11^{O}N and longitudes 1^{O}E and 3^{O}W. Agro-ecologically it is divided into six zones as shown in Fig. 1. These zones are (a) the coastal savanna, (b) the high rainforest, (c) the semi-deciduous rain forest, (d) the forest-savanna transitional, (e) the Guinea savanna, and (f) the Sudan savanna. The annual dependable rainfall of the zones, in order of listing is 762 mm, 1,524 mm, 1,143 mm, 1,016 mm, 889 mm, and 762 mm (3). The Sudan and Guinea savanna zones have unimodal rainfall (May-October) but the other zones have a bimodal rainfall pattern with March-July designated as the major rainfall season and September-November designated as the minor rainfall season.

In general, soils of Ghana are low in organic matter except on newly cleared land in the forest area. Soils of the Guinea and Sudan savanna zones are particularly deficient in organic matter. While phosphorus content of soils in Ghana is low, potassium is said to be fairly high in these soils. The pH of most soils falls between 5.5 and 7.0.

Soya Bean Introduction

Introduction of soya bean into Ghana through official channels began in 1909. The aim then was to get farmers to grow the crop as an additional food item and also as a possible export item. Between 1909 and 1956, seventeen annual trials, spread over more than 12 locations stretching from Asuansi on the coast to Tono on the northern border of Ghana, were conducted with about 40 varieties (2). The initial results of trials up to 1942 were discouraging, but later, probably as the trial officers learned to handle the crop better, yields began to rise. In the early 1950s yields of 1,457 kg/ha could be recorded in some trials. Some of the varieties included in these trials were Fort Lamy, Trinidad, Malaya, Pero, Mamloxi, Acadian, Avoyelles, CNS, Ogden, Pelican, Ralsoy, Lassa No. 4, Benares, 28EB, Black Forage, and Java Forage.

From the beginning, one of the problems that stood in the way of cultivation of soya beans was uneven establishment in the field. Yield levels depended very much on percentage emergence of seedlings; when emergence was satisfactory yields were quite good, but when emergence was poor, near zero yields were obtained. This poor field establishment, which was then attributed solely to loss of seed viability in storage, served to discourage farmers from growing the crop even though a price of 4d/lb of seed had been fixed by government to foster its cultivation. One other constraint to the cultivation of soya bean for food was that farmers complained that it took too long to cook.

In 1961 (2) concluded that, although soya bean would grow and yield up to 1,457 kg/ha, large-scale cultivation could not be recommended until the problem of occasional complete failure, due largely or wholly to loss of seed viability, had been solved. Of the varieties tested, Malaya, which seemed to retain its viability longer, and Mamloxi, with a large white seed that took less time to cook, received special mention.

Initial Yield Evaluations

There was a lull in investigations on soya beans from 1957-1965. Beginning in 1966 new introductions were made, mainly from the United States, and tested. Results of yield trials on two locations--Kwadaso and Kpong--between 1967 and 1972 with the best of the introductions are presented in Table 1.

Trials at Kwadaso were not inoculated. Fertilizer rate of 70, 36, and 28 kg/ha of NPK was applied before planting. The trial at Kpong in 1972 was inoculated with Nitragin "S" culture. The plants at Kwadaso were spaced 15 cm and 30 cm for short and tall (above 40 cm) varieties respectively within the row. Distance between rows was 76 cm. In the trial at Kpong in 1972, plants within the row were spaced at 5 cm intervals.

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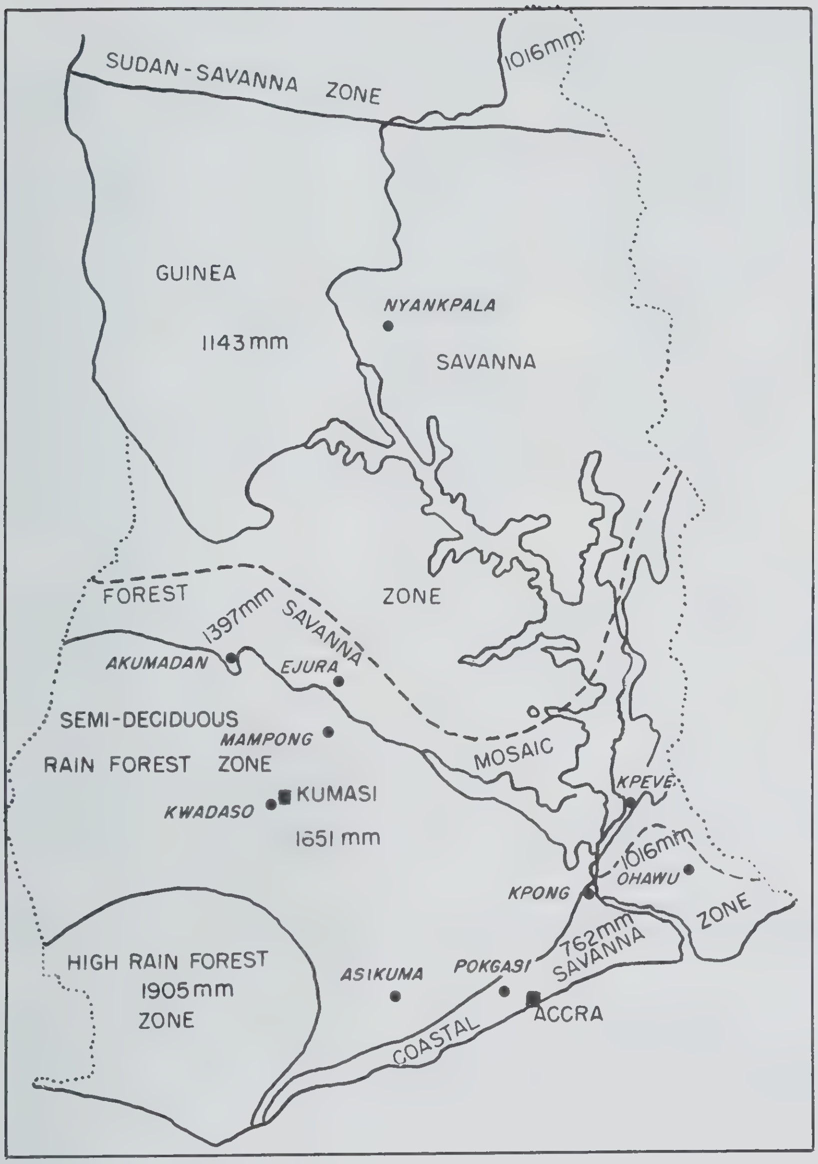

Fig. 1. Map of Ghana showing agro-ecological zones.

From these initial yield trials, F62-3977 emerged as the highest-yielding variety in the major season at Kwadaso. Different varieties had been tried for different numbers of minor seasons at Kwadaso. Among the varieties tried the longest (5 seasons), Hill, with a mean yield 1,319 kg/ha, was the best yielder. Owing to the erratic nature of rainfall in the minor season at Kwadaso, yields varied widely in this season.

Probably as a result of the use of better-adapted varieties and the application of better cultural practices involving inoculation of seed and optimum spacing of plants, yields in 1972 were considerably higher at Kpong.

Present Production and Utilization

In Ghana there are now four main feed manufacturing mills. These are the Tema Food Complex Corporation, Pomadze Enterprises, Agricare, and Ghana Poultry Feed Mills. These feed manufacturers imported about 4,000 tons of soya bean meal and cake in 1972 at a cost of 1,406,000 cedi (₵ 1.15 = $1.00) for preparing concentrates for sale to producers of livestock (J.F. Koampah, personal communication). In addition, soya bean oil for cooking purposes worth ₵ 177,134 was also imported (F. Ghartey, personal communication).

Very little soya bean cultivation is now being undertaken even though the crop has been known in Ghana for a long time now; only about 86 hectares (200 acres) are being cultivated at this time.

Table 1. Seed yields (kg/ha) of soya bean varieties in two locations in Ghana, 1968-1972.

Varieties	Kwadaso Major seasons 1968-1969	Kwadaso Minor seasons 1968-1972	Kwadaso Range minor seasons	Kpong Minor season 1970	Kpong Major season 1972
F62-3977	2,967	1,117 (5)[a/]	181-2,137	1,766	--
2G-1	2,642	845 (4)	219-1,555	--	--
Otootan	2,340	1,034 (4)	201-1,882	1,242	--
A62-8Nonod	1,169	934 (5)	162-1,724	1,976	--
A62-7 Nod	936	1,170 (5)	457-2,068	1,879	--
Lec	913	1,016 (5)	196-1,679	2,124	--
Hill	467	1,319 (5)	335-2,348	1,972	--
Meneira	--	2,072 (2)	1,521-2,624	--	--
Hawkeye	--	1,900 (2)	1,177-2,624	--	1,728
Hardee	--	1,892 (2)	1,160-2,500	--	--
Davis	--	1,824 (3)	1,036-2,746	--	--
Hampton	--	1,112 (3)	810-2,137	--	1,934
CES 407				--	1,483
CES 486				--	2,479
Improved Pelican				--	3,112
Clark 63				--	2,479
CMS				--	1,446
Hale 3				--	2,817
Chung Hsing No. 1				--	2,761
Amsoy				--	2,648
Kent				--	3,137
Shelby				--	2,028
Bossier				--	2,148
Chippewa 64				--	2,836

[a/] Numbers in parentheses indicate number of seasons of testing.

In Ghana there is a Grains and Legumes Development Board whose function includes the promotion of the cultivation of cereals and grain legumes. Realizing that Ghana could ill afford the huge import bill of ₵ 1.5 million for soya bean meal and oil--which, in any case, was bound to grow in the years ahead--the board became interested in the investigations that had been done on the crop. This interest was stirred not only because the crop's production could stem the tide of its importation for the manufacture of feed but also because the soya bean could be used as a rich source of protein for human consumption and could be developed as an export crop. Furthermore, since the soya bean had no traditional markets in Ghana, the board could easily control its marketing for the benefit of both the farmer and any industries using it. If most problems are solved, the board proposes to have about 480 hectares (1,200 acres) cultivated in 1975. This would be increased to 1,200 hectares (3,000 acres) in 1976, 3,200 hectares (8,000 acres) in 1977, and 4,800 hectares (12,000 acres) in 1978. The projections indicate that after 1978 Ghana should be self-sufficient in soya bean meal and oil.

RECENT INVESTIGATIONS

Yield Trials

As a result of the interest shown by the Grains and Legumes Development Board, studies on the crop were stepped up. Even though earlier work had indicated that fairly good yields could be expected, it was felt that investigations had to be expanded to cover a wider area of the country, to learn more about the yield levels and general performance of varieties in the different agro-ecological areas.

The first of the country-wide yield trials were conducted in 1973. In these trials fertilizer was applied at the rate of 30 kg N, 50 kg P, and 30 kg K per ha. Seeds were inoculated with Nitragin "S" culture. The trials were conducted on seven locations in the major season and on three locations in the minor season. Results of these trials are presented in Tables 2, 3, and 4. In the major season the highest yields were obtained from sites on the inland areas of the coastal savanna and the forest savanna transitional zones--namely, Kpong, Ejura, and Ohawu. Lowest yields were obtained from Legon which is located in an area with very low rainfall. Mean yields over all locations indicated F62-3977, CES 486, CES 407, and Bossier as the highest-yielding varieties. In the minor season, yields were only about one-third to one-half those in the major season at Kwadaso and Kpong. At Kumasi, however, yields were comparable to major season yields. Hand irrigation was applied at both Kpong and Kumasi.

Number of days to flowering bore some relationship with latitude. Number of days to flowering increased with increase in latitude. No such relationship was observed in latitude versus days to maturity and latitude versus plant height. In general, plants grew taller, flowered later, and matured later in the major season than in the minor season. F62-3977, CES 407, and CES 486 were the latest to flower. Improved Pelican was the tallest and lodged badly.

Seedling Emergence

The main problem that frustrated the planned commercial cultivation of soya beans when they were first introduced in Ghana was the crop's uneven establishment in the field. Although the seed is now stored at a temperature 4.4°C and relative humidity of 40 percent the problem still exists. Some preliminary experiments have been done to determine whether the problem arose before or after the seed was sown.

In April 1973 and 1974, a laboratory germination test was conducted on a number of varieties (harvested in mid-December of the previous year and stored in a cold room) after which percentage germination was calculated. At the same time, seeds of the same varieties were planted in the field. Percentage of seedlings that emerged in 10 days was calculated. Similarly, percentage germination in the laboratory and percentage seedling emergence in the field, of seeds harvested in August 1973, were tested in September of the same year.

The mean percentage germination in the laboratory and seedling emergence in the field in April 1973 and 1974 and the same data measured in September 1973 are presented in Table 5. In the April tests, the range in germination in the laboratory was 18 to 100 percent with a mean of 66.5 percent. In the field the range was 10 to 60 percent and the mean was 33.8 percent. Thus the mean seedling emergence in the field was only about half the germination obtained in the laboratory. It appeared that factors causing loss of seed viability and soil-related factors were equally responsible for poor emergence of seedlings of soya beans in the major season. By contrast, mean percentage laboratory germination (42.9 percent) and percentage seedling emergence in the field in the minor season (42.4 percent) were quite close. This seems to indicate that the spotty seedling emergence in September plantings was related mainly to the preplanting viability of the seed itself. It may be noted that the mean percentage laboratory germination in September was much lower than April. It has been observed that seed harvested in the major season is generally poorer in quality, which may have contributed to the inferior germinability in the September laboratory tests.

To initiate an investigation of the various soil-related factors that may contribute to sparse seedling emergence, effect of sowing depth and number of seeds per hole on emergence have been studied. The sowing depths and numbers of seeds per hole employed and the results obtained are shown in Fig. 2 and Table 6.

Sowing depth did not significantly affect seedling emergence (Table 6). Grass mulch improved seedling emergency by 24 percent over plantings at the same depth and with the same number of seeds per hole. Percentage seedling emergence decreased with increase in number of seeds per hole. However, the absolute number of emerged seedlings increased with increase in number of seeds per hole even though not proportionately. For instance, sowing at a depth of 1.27 cm with 3 seeds per hole compared to 1 seed per hole resulted in twice as many seeds emerging as against the expected thrice as many.

Table 2. Soya bean grain yield (kg/ha), major season at seven locations, Ghana, 1973.

Variety	Kpong	Ejura	Ohawu	Kumasi	Nyankpala	Kwadaso	Legon	Mean
F62-3977	3,771	--	3,084	457	2,789	2,267	--	2,474
Bossier	3,003	2,801	2,442	2,392	1,671	990	839	2,018
Improved Pelican	3,100	1,892	2,085	2,356	1,109	1,518	694	1,822
CES 486	3,114	3,496	1.750	2,042	1,489	1,086	1,530	2,073
CES 407	3,629	3,431	2,012	2,623	1,350	407	1,019	2,067
Kent	--	997	719	457	371	575	730	642
Hardee	4,090	787	--	3,175	--	--	1,077	1,842
Hill	2,335	1,065	1,392	438	1,239	1,193	530	1,170
Davis	4,003	--	555	--	352	--	1,476	1,572
Mean	3,381	2,067	1,755	1,743	1,296	1,148	987	
LSD 05	506	527	440	1,189	338	686	--	
CV	19 %	14 %	39 %	52 %	20 %	40 %	--	

Table 3. Soya bean grain yields (kg/ha), minor season at three locations, Ghana, 1973.

Variety	Kwadaso	Kumasi	Kpong
F62-3977	775	2,559	1,684
Bossier	562	2,348	1,054
Improved Pelican	543	--	976
CES 486	425	2,899	1,754
CES 407	316	3,212	1,543
Kent	507	1,521	684
Hardee	700	1,955	551
Hill	518	1,813	432
Davis	956	--	535
V-1	805	4,032	--
Dare	855	--	--
Disoy	958	--	--
Meneira	1,009	--	--
Ototan	871	--	--
Mean	700	2,542	1,024
LSD (0.05)	191	276	292
CV	23 %	19 %	10 %

Table 4. Range in days to flowering, plant height, and days to maturity of soya bean in seven locations in the major season and in three locations in the minor season, Ghana, 1973.

Variety	Range in days to flowering		Range in plant height (cm)		Range in days to maturity	
	Major season	Minor season	Major season	Minor season	Major season	Minor season
F62-3977	41-58	34-42	52-97	59-74	94-111	94-106
Bossier	36-41	38-39	25-82	43-59	91-110	87-110
Improved Pelican	31-42	38-39	33-113	87-68	84-111	90-108
CES 486	35-50	35-43	25-103	38-69	97-118	87-108
CES 407	34-57	38-43	42-109	38-70	95-118	92-108
Kent	29-39	30-39	23-82	38-57	78-115	86-100
Hardee	35-41	30-35	19-67	27-50	85-103	87-101
Hill	31-41	30-35	28-64	23-48	76-108	87-100
Davis	32-35	29-36	20-63	23-31	82-96	85-102
V-1		32-36		27-46		85-96
Dare		29		30		95
Disoy		29		29		93
Meneira		30		33		85
Otootan		37		64		102

Table 5. Percentage germination and field emergence of soya bean varieties.

Variety	Major seasons 1973-1974		Minor season 1973	
	Percentage laboratory germination	Percentage field emergence	Percentage laboratory germination	Percentage field emergence
Otootan	100	60	100	86
Vicoya	95	47	40	36
Hawkeye	93	27	40	42
Semmes	81	47	60	63
CES 486	80	31	--	--
V-1	78	33	--	--
Meneira	75	22	20	40
Improved Pelican	75	53	20	13
Seminol	75	57	--	--
Bossier	70	39	20	22
Dare	68	22	40	43
Kent	65	54	--	--
F62-3977	65	24	40	77
Disoy	61	22	40	56
Hill	59	10	40	19
Bragg	57	28	60	53
Biloxie	54	20	--	--
Davis	31	24	--	--
D58-4168	25	28	40	16
Hardee	18	27	40	27
Mean	66.50	33.75	42.85	42.35

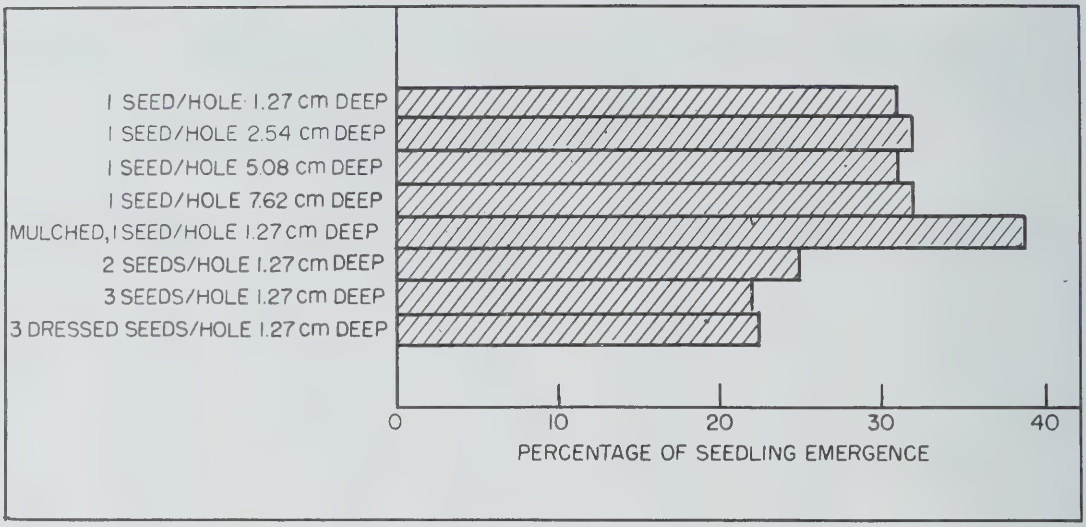

Fig. 2. Effect of sowing method on percentage seedling emergence of soya bean, Ghana, 1974.

Table 6. Number of seeds emerged in the field, as percentage of method (a).

Planting method	Emergence percentage of (a)
(a) 1 seed per hole 1.27 cm deep	100
(b) 1 seed per hole 2.54 cm deep	102.8
(c) 1 seed per hole 5.08 cm deep	99.4
(d) 1 seed per hole 7.62 cm deep	103.2
(e) Mulch, 1 seed per hole 1.27 cm deep	124.4
(f) 2 seeds per hole 1.27 cm deep	147.7
(g) 3 seeds per hole 1.27 cm deep	205.8
(h) 3 dressed seeds per hole 1.27 cm deep	207.7

Seed Quality

It has been observed that seed harvested in the major season, particularly in the semideciduous rain forest zone, tends to be poor. This poor quality manifests itself in purple stain (*Cercospora kikuchii*) or other fungi-infected seed and shrivelled or generally misshapen seed.

Nodulation

When inoculants are not applied nodules have not been observed on roots of soya bean. It is a normal practice now to inoculate seeds before they are planted. In one trial involving 15 varieties in 1974 on a field of pH 5.5, nodule counts and weights were recorded at flowering and 3 weeks later. At flowering a range of 1 to 3.7 and a mean of 1.9 nodules per plant were recorded. Three weeks after flowering the range was 2.3 to 8.4 nodules per plant with a mean of 3.8. Mean weights of nodules at flowering and three weeks after flowering were 5.95 and 39.80 mg respectively.

PESTS

An experiment was set up in 1973 to study the various insect pests associated with soya bean and the extent of damage caused by them. The surveys of the pest species were done by regular plant and flower inspection and "sweeping." The numbers of insect pests found were listed under the plant parts they attacked (1).

Leaf Feeders

The leaf-feeding insects appeared during the early stages of the crop and were common during the preflowering stage. They, especially the caterpillars, fed on young plant foliage. The peak of activity occurred during the preflowering stage. Among the leaf feeders, 13 Lepidoptera, 7 Othoptera, and 15 Coleoptera were identified.

Sap Feeders

Unlike the leaf feeders, the populations of the sap feeders (Heteroptera) reached a peak during the pod-forming period. The Homoptera species were generally leaf and shoot sappers and they were much more numerous at the preflowering stage than at other times. In this survey 13 Heteroptera and 7 Homoptera were identified.

Root Feeders

Among the root feeders were mealy bug (Homoptera) found at the base of the plant below ground, *Brachytrypes membranaceus* Grylidae (Othoptera) which mainly attacked young plants, and *Pseudocanthotermes militaris* Termidae (Isoptera).

Pod-boring Insect

Cydia sp. *nr plychora* larvae fed on seeds in nearly mature pods.

The results of the study indicated that no insect pest was of serious economic importance on soya bean around Kwadaso. However, (Heteroptera) *Riptortus tenuipes* and *Piezodorus* sp. are more likely to be of potential threat to the crop during pod formation, as shown by their population build-up.

DISEASES

No serious disease problems have been encountered. However, diseases such as bacterial pustule *Xanthomonas* sp., charcoal rot *Macrophomina phaseoli*, *Cercospora sojina*, leaf spot and web blight *Rhizoctonia* sp. have been observed. The last named was present in 1974 major season at Kwadaso, particularly on early-maturing varieties such as Davis, Disoy, and Dare.

Mangement Investigations

Since a good variety can perform best only when it is grown under optimum conditions, experiments on various aspects of management have been initiated. These include investigations into optimum planting time and optimum row spacing of different genotypes of soya beans, and investigations on fertilizer rates involving nitrogen ranging from 0 to 90 kg/ha and phosphorus ranging from 0 to 90 kg/ha while keeping potassium at 56 kg/ha. Also being investigated are the effects of the application of molybdenum and various cultures of inoculants from different countries on performance of soya beans in Ghana.

CONCLUSION

Although the soya bean was first introduced into Ghana some 65 years ago it is only now being rediscovered, probably under pressure from the needs of the growing livestock industry. Up to now disease and insect problems have been minimal. Yield trials show that expected yields can be quite high and indications are that there is a fairly bright future for the crop. One problem which needs solution immediately is the spotty field establishment which has plagued attempts at commercial production of the crop in the past.

Acknowledgment

The data on yields, days to flowering, days to maturity and plant height were presented by R.B. Dadson, A.N. Aryeetey, and L. Jones to the Soya Bean Committee of Ghana, of which they are members.

REFERENCES

1. Agyen-Sampong, M. 1974. 1973 annual report, Crops Research Institute. Kwadaso, Kumasi, Ghana.

2. Snow, O.W. 1961. Soya bean in Ghana, a preliminary note based on annual reports. Spec. Rpt. Ministry of Agriculture. Accra, Ghana.

3. Ussher, A.K.L. 1969. Climatic maps of Ghana for agriculture. Ghana Meteorological Services. Legon, Accra, Ghana.

DISCUSSION

T.I. ASHAYE: Your problem on germination implies multiple planting; is this so?

H. MERCER-QUARSHIE: No, this is not exactly the situation. Since we know from experience that we generally get about 30 percent seedling emergence we plant thrice as many seeds to get a full stand. In other words, although we require distance between plants in the row to be 6 cm, we plant the seeds 2 cm apart, dropping 1 seed per hole.

ASHAYE: A yield of 4,000 kg/ha cannot be reconciled with Table 1 above. Is this an occasional yield? What in fact is the range of yield?

MERCER-QUARSHIE: With the method of planting described above, a full stand is assured and seed yields of 4,000 kg/ha are obtained from high-yielding varieties under favorable environments as indicated in Table 2. The range in yield is as indicated in Tables 1, 2, and 3.

G. JENBERE: It has been indicated that there are two major problems in introducing soybean for household consumption in Ghana. These problems are (1) too long to cook, (2) taste is not appealing. Are you considering these two problems in your experimental variables?

MERCER-QUARSHIE: Among the problems that frustrated the attempt to introduce soya beans into Ghana in the early 1900s was the complaint by growers that soya beans took too long to cook and also that their taste was unappealing. The aim of the investigations now is to develop soya beans for meal to be used in feeds, and for oil for various cooking purposes. Therefore nothing is being done now in determining the acceptability of the soya bean seed as food for humans. This is not to say this will not be done in future.

S.M. FUNNAH: How do farmers in Ghana grow soybeans--that is, either in rows or at random?

MERCER-QUARSHIE: Almost no farmers grow soya beans in Ghana. The few who do, and these can be counted on the fingers, grow them in rows.

N.O. AFOLABI: Comment, your seed should not deteriorate so fast if stored in a cold room after drying to between 8 and 9 percent moisture content.

MERCER-QUARSHIE: There are a number of factors that can cause the loss of seed viability even before it is stored. It is thought that some of these factors might have contributed to the low seed germination percentage recorded in the report, even though such seed had been dried to 10 percent moisture and stored in a cold room.

Soybean Cultivation and Production in Iran

M.C. Amirshahi

Soya bean is a new crop in Iran, having been introduced only about 36 years ago. About 5 years ago, interest in soya bean cultivation started to increase sharply.

Soya is regarded in Iran as a source of edible vegetable oil. Reports show that in 1973 the national oil consumption was about 250,000 tons, of which some 190,000 tons were vegetable oils and the rest animal oils. The national vegetable oil production in Iran in 1973 was 70,000 tons and the balance--120,000 tons, 80 percent from soya bean--was imported. The principal sources of vegetable oil in Iran are cotton seed, which supplies 35,000 to 40,000 tons of oil; sunflower, supplying 25,000 to 30,000 tons; and safflower, sesame, and soya bean, supplying the rest.

Soya bean with 18 percent oil and 38 percent protein content, has aroused a great deal of interest as a source of protein for animal feed.

The total area under soya bean cultivation and soya bean production in Iran have been reported as follows:

Year	Area (ha)	Production (tons)	Yield (tons/ha)
1972	7,000	9,700	1,380
1973	6,360	9,540	1,500
1974	21,794	31,000	1,422

Considering the total vegetable oil consumption in Iran, and with the rate of population increase and higher demand of vegetable oil, the government of Iran has focused more attention toward oilseed crops, particularly sunflower, safflower, and soya bean.

Three-fourths of the soya bean crop is cultivated in the northern littoral plain of Iran--that is, the Caspian Sea area, Mazandaran and Gorgan--and only one-fourth in the central plateau and the west. The soya bean cultivar most used in the Caspian Sea area is Hill and, due to high precipitation and generally rich soil, the average yield is rather high. In most good farms, yields of 3 to 3.5 tons of soya bean are usual. In the central plateau and western Iran, cultivar Clark 63 has been released and cultivated under irrigation.

It is estimated that by next year the total soya bean area will be increased to 60,000 hectares, of which 50,000 hectares will be in the Caspian. It is estimated that in the next 5 years the total area for soya bean will be raised up to 100,000 to 120,000 hectares.

The main soya bean cultivation problems in Iran are as follows:

1. Water is a limiting factor in crop production in Iran. Soya needs to be irrigated regularly at the exact time when other main summer crops such as cotton, rice, sugar beets, and sunflower also need it. In the Caspian Sea area, where precipitation is high, water is not much of a problem but in the central plateau and western Iran, irrigation limits the expansion of this crop.

2. Because soya bean is a new crop in Iran, the soil lacks the necessary inoculum. Lack of bacteria inhibits nodule formation and lowers yield. In 1974 the Oil Seed Company distributed more than 20,000 packets of inoculum along with soya seed to the farmers.

3. Though fertilizers, especially phosphorus, are supplied, deficiency of potash and some other minor elements is exhibited in many soy farms.

M.C. AMIRSHAHI: Vice Dean, Faculty of Agriculture, Teheran University, Karadj, Iran.

4. The increasingly high cost of farm labor means that mechanization of soya bean cultivation, particularly harvesting, is going to be a necessity in the near future.

5. Other problems, such as finding the exact date of planting, the best density or rate of seeding, and the early- and high-yielding varieties, must be solved before expanding the soya bean cultivation in Iran.

Regarding diseases and pests of soya bean, up to now no serious problem has been raised, but pests such as *Tetranychus telarius*, *Hylemya cilicrura*, *Agrotis segetum*, *Spodoptera exigus*, *Heliothis dipsacea*, *Prodenia litura*, *Phytometra gamma*, and *Aphis gossypii*, have been collected from soya farms. Diseases caused by fungi such as *Peronospora manshurica*, *Sclerotinia rolfsii*, *Rhizoctonia solani*, *Sclerotium bataticola*, *Alternaria* sp., and *Cercospora kikuchii*, and also some virus diseases, have been reported in Iran. The diseases of soya bean in Iran are discussed in more detail in a separate report.

To solve the breeding and agronomic problems regarding soya cultivation, a vast research program is needed. At present, the Seed and Plant Institute of the Ministry of Agriculture, with the help of Yugoslavian experts, have started a research program, and the Oil Seed Company, with the cooperation of the agricultural colleges, is carrying out research programs to find soya varieties suitable for each region and to solve various agronomic problems.

The College of Agriculture of Tehran University at Karaj is cooperating with the University of Illinois on variety trials, and we have separate experiments for date and rate of planting combined with variety trials. Some of the soya bean varieties in variety trials have yielded 4 to 4.5 tons per hectare. Also, research projects are carried out for determining the water and fertilizer needs of soya bean on the college farm.

The future of soya bean in Iran is very promising and we feel that a closer cooperation for research among the different organizations and institutes concerned is necessary. We certainly appreciate the guidance of the International Soybean Institute in helping us solve problems that will promote the expansion of a new crop such as soya bean.

DISCUSSION

M. VON OPPEN: How is the spectacular increase in area under soybeans being promoted? By the government? By the industry?

M.C. AMIRSHAHI: (1) By informing the farmers of the benefits of soya bean farming through extension agents. (2) Due to the high cost of cotton production the farmers are switching to other crops like soya bean. (3) The soya bean price has been raised by the Oil Seed Company. (4) Subsidies and loans in the form of seed, fertilizers, and even money are paid to interested farmers by the Oil Seed Company and the government.

Problems of Soybean Diseases in Iran

F. Eskandari

Since 1971, along with the development of soybean cultivation in Iran, efforts have been made by the Department of Plant Protection, College of Agriculture, University of Tehran, to identify the important diseases of this crop. Three important diseases have been so far reported:

Soybean Downy Mildew

Soybean downy mildew is caused by *Peronospora manshurica* (Naamoff) Syd. This disease has been found in the northern part of the country, i.e., the Caspian Sea area. Investigations have been undertaken to study the distribution, damage, economic importance, and methods of control. Efforts have also been made to study the morphology, biology, ecology, and means of natural transmission of the fungus. According to some experiments, the soybean varieties Abura, Acme, Amsoy, Bragg, Chippewa, Kent, Lindarin, Meriet, Wilson, and USA are relatively resistant to different races of this fungus.

Soybean Mosaic Virus

In 1971, not more than 40 percent of the most susceptible soybean varieties were found infected by soybean mosaic virus. This disease has recently become widely distributed in Iran.

Survey of one of the fields in Kordkooy and Gorgan in August 1974 showed that 70 percent of the variety Hill was infected by this virus. At present, this disease occurs in soybean fields of Amol, Babol, Behshahr, Chalus, Gorgan, Karadj, Rasht, Sari, and Shahi.

The varieties Blackhawk, Chippewa, Clark, Dolman, Dorman, Harasoy, Harasoy 63, Hill, Kanrich, and Wayne were tested for resistance, and Blackhawk, Chippewa, Clark, and Dolman were found to be resistant to the virus.

Soybean Wilt

Soybean wilt has been reported from Gorgan and Mazandaran. The damage can be serious. *Rhizoctonia solani* Kuehn has been shown to be the causal agent of this disease. Some investigations have been initiated to study various aspects of the disease and methods for its control.

F. ESKANDARI: Associate Professor, Faculty of Agriculture, University of Teheran, Karadj, Iran.

Planting Soya Bean in Iraq

Fadhil-Alzubaidi

With the development of the animal resources of Iraq the need arises for good stall-food, and since soya bean contains a good quantity of fats and proteins, it can meet this need as a poultry stall-food.

In the past, soya bean was unknown to the Iraqi farmers and its cultivation was not practiced on the state farms and it was not used by the technicians. It was known only theoretically in colleges and agricultural institutes. Within the last four years, however, soya bean cultivation has been started in Iraq in the form of tests by Iraqi agricultural technicians. Broad research studies and scientific tests have been initiated to find out the best ways of soya bean cultivation in Iraq and many training stations have been opened (in Mosul, Alhawijah, Suweira, Allatifiyah, Abu Guraib). The varieties that have been cultivated are Lee and Bragg.

The General State Company for Plant Production planted 2,000 donum (1 donum = 0.25 ha) of soya bean in Suweira during the planting season of 1974, to find out the best methods for cultivation, including the best system and time for planting, and the machinery needed.

METHODS OF CULTIVATION

Three methods of cultivation have been tried: the flat system, the dry furrowing system, and the wettable system.

The Flat System

In the flat system (without furrows) a cotton seed drill was used for planting. Other data from this experiment are as follows:

Period	Number of times irrigated	Temperature (°C)	Wind speed
June 18-30	1	37-42	Medium-fast
June	4-5	43-46	" "
July	4-5	46-48	" "
August	3-4	47-46	Slow-medium
September	2-3	37-45	" "

Several problems were discovered in this system. At the time of watering, the rows were covered with water because of the unlevelled ground, which caused formation of a solid layer of soil over the rows. This stopped or delayed the germination. We suggest this method be changed by levelling the ground and by giving special attention to the first watering.

The Dry Furrowing System

In the dry furrowing system, the variety used was Lee and two machines were used--a cottonseed drill and a wheat or grain drill. A corn drill was also considered but was not quite successful. The periods of cultivation and machinery used were as follows:

First block	June 10-June 20)	Cotton planter
Second block	June 21-July 5)	
Third block	July 6-July 20) July 21-July 30)	Grain drill

FADHIL-ALZUBAIDI: Agricultural Engineer, General State Company for Plant Production, Baghdad, Iraq.

The space between furrows was 70 cm, space between the plants was 20 to 25 cm, and depth of seed was 3 to 4 cm. Planting rate was 12.5 kg/donum. Fertilizers were applied at a rate of 50 kg/donum, a combination of superphosphate and complex at a ratio of (2:1) (super:comp.)--19 to 20 kg/donum P_2O_5 to 15 kg N.

The grain seed drill was found to be more successful than the cotton seed drill. Other results obtained were as follows:

Planting period	Date of first bloom	Date first pods formed
June 10-June 20	August 19	September 2
June 21-July 5	August 25	September 4
July 6-July 20	September 1	September 7
July 21-July 30	September 6	September 11

The Wettable System

In the wettable system, the Lee variety was tested and the cotton seed drill was used for planting. Other details were as follows:

Planting period	Number of times irrigated	Temperature (^{o}C)	Wind speed
First block June 5 to June 15	3-4	43-46	Medium-fast
Second block June 16 to June 25	4-5	46-48	" "
Third block June 26 to July 2	4-5	46-48	" "
September	2-3	73-45	Slow

Results obtained from this system in 1974 were:

Planting period	Date of first bloom	Date first pods formed
June 5 to June 15	August 9	August 17
June 16 to June 25	August 17	August 26
June 26 to July 2	August 22	September 2

In a 1973 test on Allatifiyah farm, two varieties were planted as follows:

Variety	Planting period	Planting rate (kg/donum)	Germination date
Bragg	April 12-April 21	8	April 21
Lee	April 21-April 30	6	May 1-May 31

Ploughing and fertilizing occurred May 12 to May 31. Average date of first bloom was June 14; average date first pods formed was August 30. Watering was stopped on October 10 and harvesting occurred on October 31 to November 12.

It was found that the spring planting resulted in good germination, but at the time of blooming the very high temperature caused the flowers to fall. This continued until the temperature changed downward, after which the pods formed. For this reason we considered this system to be unsuccessful and more costly than the autumn planting.

PESTS AND DISEASES

The main insect pests of soya bean in Iraq are red spider, Laphigma, and white fly. This crop may be affected by damage from rabbits and rodents. The main diseases caused by microorganisms are wilt and virus mosaic.

SUMMARY

Based on the planting at Suweira in 1974, the following conclusions have been reached:

1. The wettable system is the best way of planting soya bean.
2. The furrowing system using the grain seed drill is also successful.
3. The flat system is considered to be unsuccessful.
4. The best time for planting soya bean is June.

In regard to machinery, the cotton seed drill is considered to be successful for the wettable system but not for the dry furrowing system. The grain seed drill is considered to be successful if used with furrows. We used these machines because we have no special machines for soya bean production in Iraq.

The economic evaluation of this experiment will be made after the harvesting period because the crop is still on the farm at this time.

Soybean Production in the Ivory Coast

A.D. Assa and K. Edi

The Government of the Ivory Coast, in order to increase the standard of living of the people of the northern savannah region in particular, and of the whole population in general, has envisaged the commercial production of soybeans.

From seeds bought from the United States (2.5 tons of Bossier) and from planting material received from northern Nigeria and Brazil, seed multiplications have been established at five different points, of which three are in the northern part, one in the northwest, and one in the central part of the country. The total area under seed multiplication is about 66 hectares.

Field trials are also being conducted with varieties received from the cooperative trials of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, and from the International Soybean Program (INTSOY).

Partial results show that, from the vegetative growth point of view, four varieties seem to do well. These include Bossier, M90, M98, and Santa Rosa. We also think that at least two of these varieties might be suitable for mechanical harvest because of the high pod set from the bottom. Furthermore, these varieties may give good yields.

The varietal trials show that yields ranging from 1,600 to 2,600 kg/ha can be obtained in the central part of the country for the 6 varieties from IITA (Bossier, Kent, Jupiter, Improved Pelican, CES 486, IGM-280-3). The same varieties grown in the south gave yields ranging from 406 kg/ha to 1,134 kg/ha. As far as the INTSOY trial is concerned, only the trial at the School of Agriculture in Abidjan has been harvested. Results are rather poor since yields range from about 240 kg/ha to 702 kg/ha. We attribute these low yields to the poor soil and poor weather conditions.

From our little experience in soybean production, we can state that soybeans can grow well in the Ivory Coast as long as we stay away from the southern part of the country.

By next year, we should be able to learn more about date of planting, density of cropping and other crop arrangement practices.

Training of the personnel involved in the program is a very important factor and arrangements are being made to define our needs in this regard.

Harvesting, drying, and storage equipment should be defined as soon as possible in order to avoid great losses in our seed multiplication schemes. In 1975, we could plant about 1,200 hectares of soybeans and the problem of harvesting, drying, and storage will become even more acute.

DISCUSSION

B.P. CHEVREAU: You have spoken about experiments in central and in northern regions in Ivory Coast. But in the central part you have few rainy seasons and in the northern part only one. I want to know in what rainy season, the first short one (like maize or peanut) or the second longer one (like cotton), you have experiments in the central region.

A.D. ASSA: In the center part of the Ivory Coast, the first season crop is planted in April and harvested in June-July. To avoid the small dry season in July up to August 7 or 10, the second season crop is planted around August 15. Results with a variety called Bertona, have shown that, generally, the second planting gave better yields than the first planting.

A.D. ASSA: Assistant Professor of Soil Science, University of Abidjan, Ivory Coast. K. EDI: Farm Manager, Ensa School of Agriculture, Abidjan, Ivory Coast.

W.J. KAISER: With the keen interest shown by the Ivory Coast in soybean production, are people being trained in various aspects of soybean production, such as plant pathology, entomology, and soil microbiology?

ASSA: Yes, there is a team of young Ivory Coast scientists involved in the program. There is a whole program of training of Ivorians for the next 5 years, both inside and outside the Ivory Coast.

S. MOUTIA: The difficulties of small experimental plots are appreciated and also the delay in getting results from small experimental programs. But how do you finance an experimental program on 60 hectares.

ASSA: At the moment it is financed by the government. The minister presents the program and gets a budget for it. But this cannot go on for long and we are looking for outside help because the Ivory Coast cannot afford it.

S. ABU-SHAKRA: It is a comment more than it is a question on your statement that large field trials are more dependable than small agronomic plot trials. I would like to mention in this connection that it is mainly important to identify your variables which contribute to the success or failure of the crop and then try to identify, control, and solve the variables. This can be done much better under small plot experimentation. The results obtained under small plot experiments are then used as the goal to be attained by farmers when they grow the crop on a large scale.

ASSA: Thank you for your suggestion--I have made a good note of it.

N.O. AFOLABI: Did you inoculate the 2½ tons of soybean you said you planted?

ASSA: Yes.

G.F. NSOWAH: Have you observed any genotype-environment interaction with varieties of soya beans grown during the main and the minor rainy seasons of the country?

ASSA: This is difficult to determine at the present time but I think better evaluation of this interaction can be made next year when several trial points will be involved.

Problems of Growing Soybeans in Khuzistan

G. Noor-Mohammadi

Khuzistan is located at 30° lat. and 48° long., in the southern part of Iran. Khuzistan is the largest province in Iran with over 3 million population. The capital is Ahwaz, with about 500,000 population.

The climate is relatively warm with $51^{\circ}C$ in July and around $0^{\circ}C$ in December, with an average of $23^{\circ}C$ in the year. The average of 10 years' rainfall is about 150 mm and the rainfall distribution is not useful for the crops.

Except in the northern part of the province in the Dezful area, we have a severe problem of saline and alkaline soil with a pH above 8 and a high E.C. The water table in the southern part of the province ranges from 1 to 5 m. Experiments have shown that having an extensive drainage project is very successful and all kinds of crops can then be grown.

A few years ago the College of Agriculture at Jundi Shapur University in Ahwaz and the Agricultural Research Center in Dezful started experiments on oil seed crops, particularly sunflower, safflower, sesame, and also recently, soybean. According to decisions made during the Eighth Oil Seed Seminar that took place at the College of Agriculture in Ahwaz last year, we had some trials on three different varieties--early-, middle- and late-ripening varieties--at the college research center and in the Dezful area as well.

Inoculating, fertilizing, plant protection, weed control, and irrigation were done on schedule but the figures showed that the yields were not satisfactory, varying from 600 to 1,400 kg/ha at the experimental plots. The most interesting point is that the late-ripening varieties that were sown at about July 20 brought a better yield than the others. The reason can be that photoperiodism effect and the reproductive temperature for the late-ripening varieties were more favorable than in the other varieties. The hot weather in June and July made the soil dry very fast; consequently two irrigations per week were necessary.

It can be summarized that current problems could be solved through:

1. Having good seed, adapted for the area.
2. Having seed that is resistant to diseases.
3. Fertilizing the soil through use of organic matter.
4. Draining the saline and alkaline land.
5. Inoculating and fertilizing at the right time.

G. NOOR-MOHAMMADI: Assistant Professor, Agronomy Department; Vice Dean, College of Agriculture, Jundi Shapur University, Ahwaz, Iran.

Soybean: An Old Crop with a New Outlook in Mauritius

S. Moutia

The current shortage of animal protein coupled with its high prices has led to a search for possible vegetable protein substitutes for human consumption. While the soybean plant and its many edible derivations were known in the East, particularly to the Chinese and Japanese, in the West it was mainly known as a source of protein for animal feed. Although such use is still the major one, developments in recent years have led to multiple use of soybean derivatives for human consumption in western countries.

In Mauritius soybean meal was never very popular as a constituent of animal feed, mainly because of its price and the distance from important centers of production. In the human diet, however, it never fell out of favor with the Mauritians of Chinese origin. In some places in Port Louis, soymilk and soybean curd are prepared in the home, and the curd is sold in the market and is available in meals in Chinese restaurants.

Interest in the production of soybean is, however, not recent. P. Boname, who can be considered a pioneer of agricultural research in Mauritius, first mentions soybean as a plant that grows very well in Mauritius (2). He reported that he had cultivated soybean for some years at the station at Reduit but the results were not good. He concluded a variety trial was obviously needed, and numerous varieties were sown at different times of the year to determine the optimum time for planting. As now, the use of sugar cane inter-lines was always mentioned in discussions of expansion of agricultural production. Boname felt that, because of its upright stand, soybean could be sown between rows of sugar cane although it would not give as good cover as most of the creeping cowpeas he knew. The sugar industry depended on animal traction for transport of canes at that time and Boname noted that soybean, harvested when the pods were half ripe, was excellent fodder, as were the dry haulms after the seed had been harvested. The plant was cultivated in the same way as the french bean and it also shares the same disadvantages of that crop, not least being the hares, which fed on soybean in preferance to french beans, a fact which Boname recalled had been observed in the United States as well.

A year later, Boname (3) called soybean a fashionable plant, referring to the huge quantities being imported into Europe and to the yields of 4 to 10 hectoliters of seed per acre obtained in the United States. "It is really a crop to try," he wrote, "being better than cowpeas in that flowering is uniform and pods come to maturity all at the same time." The 1910 trials at Reduit had given better results than those obtained in the past. When sown between December and March, soybean matured in 2½ to 3 months, yielding 7 to 8 hectoliters of well-formed seed per arpent of full stand, or 6,000 to 7,000 kg of green fodder. In addition to hares, the other pests were birds, snails, and the bean fly Agromyza.

Soybean was planted on a small scale in Mauritius in 1910 and the not very encouraging results were thought to be perhaps due to absence of the special bacteria--the particular Rhizobium strain--which the newly introduced legume required. Boname could not agree, however, because he had observed numerous nodules on the roots and these nodules were sometimes of exceptional size. The sowings, he felt, had been made at the wrong time of year and the seedlings had been destroyed by the bean fly.

Naturally Boname makes no mention of the photoperiodic response of soybeans, but says that, in common with many similar plants, it can be sown throughout the year. But at certain times, varying with locality, the bean fly is sufficiently important to cause death of all young plants even in seasons otherwise suitable for development of the plant. Again he suggests that the best season for the french bean in a given region would also be the most favorable for soybean.

Boname's 1910 experiment yielded enough seed to permit analysis and it is worth reproducing here (Table 1) the first published results of soybean research in Mauritius.

S. MOUTIA: Principal Agricultural Officer, Agricultural Services, Ministry of Agriculture, Natural Resources and Environment, Reduit, Mauritius.

Table 1. Percentage analysis of soybean, groundnuts, and sunflower seeds, and soybean plants and pods as fodder (2).

	Soybean seed yellow	Soybean seed green	Groundnut kernel	Whole sunflower seed	Soybean plant including pods as fodder
Water	7.87	8.36	7.23	9.25	78.60
Minerals	4.62	4.64	2.40	2.94	1.84
Cellulose	4.90	4.80	3.08	25.87	6.80
Fats	13.66	19.20	45.12	26.83	0.84
Sugars	9.20	6.10	--	--	0.57
Nonprotein	18.25	24.85	13.36	18.95	6.90
Protein	41.50	32.05	28.81	16.16	4.45

As Mauritius is in the Southwest Indian Ocean near latitude 20° it is in the path of tropical storms, known as cyclones, which occur more frequently in the summer months coinciding with the period suggested by Boname as suitable for growing soybean. It is therefore not quite unexpected to read in his 1911 report (3) that soybean cultivation had not come up to expectation, mainly "because of the cyclones which had come one after the other in the early months of the year." Yet he was not to be deterred, for he was conscious of the contribution that soybean, in common with other legumes, could make in improving soil fertility and for use as animal feed. It was unfortunate that they were so difficult to cultivate, owing to risk of total failure caused by cyclones or heavy rains, or later damage by the bean fly, birds, or hares--which sometimes left one with no seed to start all over again the next year.

As a possible solution to these problems, Boname suggested that a larger number of soybean varieties be obtained and tried, from which a more resistant and vigorous variety than those already tested, could be selected. Apart from the yellow- and green-seeded varieties mentioned in Table 1, there was no indication of variety names or from where they had been introduced. In 1914 the Department of Agriculture, which had been established only a year earlier, introduced what Leclerc (4) called "a good collection of 10 varieties" of soybeans from India. They were planted in September 1915 at the Royal Botanic Gardens in Pamplemousses, but because October was the driest month in the region, the crop was severely affected by drought. The bean fly Agromyza is again mentioned as a pest. The yields were most unsatisfactory and it is reported that four varieties whose names were not recorded, failed to produce seed. The best yield is credited to Black Early Type No. 2 with 126 kg/arpent.

Others have mentioned soybeans, both local and imported varieties, among the foodcrops that have been experimented with in Mauritius, but the results apparently did not warrant publication or the experiments were never completed. However soybean plants were grown by the Department of Agriculture. O'Connor (9) reports that plantations of different varieties were made and that "seeds are to be distributed free to the public." The offer was not utilized to any extent, but it was maintained and North Coombes (5) reported free distribution of seed to government institutions and school gardens, and mentions various unnamed varieties of soybeans as being among the more interesting of these seeds.

When vegetable seed production was started by the Department of Agriculture, 4 kilos of soybean seed were produced in the first year, 1943, though none were produced in 1944-1946 (8). J.H. Julien (personal communication, 1974) reports that for many years soybean was produced on the Department of Agriculture stations and that the seed was scrupulously kept from year to year to be sown every winter. The crop was poor, however, and had to be protected against hares, which were particularly fond of the young plants.

The very little interest shown in the crop by the public is again referred to (6) but the field trials were continued. Yields varying between 200 and 300 kilos per acre were obtained from several unnamed varieties. A year later the following varieties were

tested: Java Forage, Brunea, Avoyelle, Nigra, Charlie, Missoy, White, Bicolor, Nanda Biloxi. New varieties introduced were Gendjah Slawi, Ruggit No. 16, No. 27, No. 29 and No. 449. "No planter so far has shown any interest in this crop," sadly writes the author, and the curtain falls, but not for long, on this compulsive crop.

In 1954 the Department of Agriculture recruited an officer to work on grassland and fodder problems, which led to the introduction of yet other soybean varieties, but only one, Masterpiece, was of any value. According to Julien (personal communication, 1974) it was much better than any other soybean he had seen growing in Mauritius. Yet even Masterpiece never found favor with the planters although the variety was scrupulously maintained from year to year in the seed collection of the Department of Agriculture.

Today, however, the interest in soybean comes from the planters themselves, who, a few years ago when sugar prices were low, started looking for a crop that could be grown on sugar cane lands and in the interlines of sugar cane. In spite of the previous failures, soybean could not be ignored. Because of its high nutritive value, its importance both as an oil and a protein crop, its short cycle of 2½ to 3 months, its adaptability to clay soils unsuitable for potatoes and groundnuts, and the possibility of growing it in interlines of sugar cane (1), soybean experimentation was resumed. In the last five years varieties have been introduced by the Ministry of Agriculture from India in 1969, and obtained through the Food and Agriculture Organization (FAO) headquarters in Rome in 1971. Other varieties were obtained from the United States, Japan, and Taiwan and put in trials by the Mauritius Sugar Industry Research Institute (1) and the Ministry of Agriculture with the cooperation of a Taiwan agricultural mission (10).

The following varieties have been grown: Bragg, Clark 63, Hardee, Hampton 266, Adelphia, Amsoy, Cutler, Dans, Grant, Harosoy 63, Hill, Hood, Improved Pelican, Kent, Merit, Portage, Ranson, Semmes Wayne, York, San Kuo, Shih, Hoko Tan, Tsai ta Kao, Hsuing No. 5, Chung Hsing No. 2, Nung yu 64-104, Palmetto, Delmar, and Lee 68. The yields have varied between 1,543 kilos and 4,683 kilos per hectare (1, 11). The average yield for 14 varieties obtained by Shaw and Oogarah (10) was 2,190 kg/ha.

The differences in yield have also been accompanied by differences in oil and protein content of the seed (1), but results were sufficiently encouraging to consider further trials to select high-yielding varieties for various regions of Mauritius. With this objective in view, the Agricultural Services have planned an intensive experimental program on soybean and have shown interest in the International Soybean Program (INTSOY). In 1974 two series of trials are being established in collaboration with the University of Illinois. As is already known, 9 countries in Africa and 33 countries throughout the world are participating in this cooperative program. The seed and the inoculum will be provided by the University of Illinois and the trials planted at two locations in the humid and subhumid zones. The commercial production of soybean in Mauritius presents problems but it is expected that, with the long tradition which the University of Illinois has in soybean research, our local research workers will get the support and the guidance required to obtain results that can be quickly passed on to the producer.

REFERENCES

1. Anonymous. 1972. Mauritius Sugar Industry Research Institute Annual Report 1971.
2. Boname, P. 1910. Rapport Annuel Station Agronomique Ile Maurice, 1909.
3. Boname, P. 1911. Rapport Annuel Station Agronomique Ile Maurice, 1910.
4. Leclerc, L.M. 1916. In Annual Report, Department of Agriculture, Mauritius, 1915.
5. North Coombes, A. 1941. In Annual Report, Department of Agriculture, Mauritius, 1940.
6. North Coombes, A. 1947. In Annual Report, Department of Agriculture, Mauritius, 1946.
7. North Coombes, A. 1961. Rev. Agric. et Sucr. Ile Maurice Vol. 40 No. 4.
8. North Coombes, A., and J.H. Julien. 1949. Bull. No. 50 Department of Agriculture, Mauritius.
9. O'Connor, C. 1932. In Annual Report, Department of Agriculture, Mauritius, 1931.
10. Shaw, S.M., and P. Oogarah. 1972. Rev. Agric. et Sucr. Ile Maurice. Vol. 51 No. 2.
11. Vyapoory, P.P. 1974. Results of trials with nine selected varieties of soybeans. In preparation.

Soybeans in Nepal

M. Panday

The area of Nepal is 56,300 sq. miles. The country can be divided into 4 agro-climatic regions as follows: (1) Himalayan regions; (2) hilly and valley regions; (3) inner Terai; and (4) Terai regions.

Our population is 11,500,000. Nearly 7.5 million people used to live in hilly regions. These hill people and the people in inner Terai used to cultivate different varieties of soybeans in the terraces at different altitudes ranging from 6,000 to 4,000 feet.

The soybean varieties grown by our local farmers may be classified according to their seed coat color as follows: Brown, black, yellowish white, greenish, and bicolored varieties such as white and black, white and brown and so on. Each particular color of seed again varies differently in seed size and shape, including seeds that are round, oval, round and flat, round and plumpy, oval and plumpy, oval and flat and so on.

Our local farmers grow these varieties along with maize in the same row; they also intercrop soybean with millet and put the soybean along the borders of rice fields. Thus soybean is the centuries-old crop in Nepal. Growing of soybean with maize and millet in intercropping is an old practice in Nepal. Not only soybeans, but almost all kinds of edible summer and winter legumes, are grown in an intercropping pattern.

In the hills the farmers can harvest soybeans only once in a year but in our Terai and inner Terai regions, if the planting season is adjusted properly, they can harvest soybean twice a year. Nearly 9,000 square miles in the inner Terai region can be utilized most successfully under soybean cultivation. Thus areas under (a) hills ranging from 6,000 to 4,000 feet, (b) inner Terai, and (c) Terai can be utilized successfully under soybean cultivation.

Due to lack of marketing facilities, our farmers grow the soybeans only for their self sufficiency, leaving a very little amount to sell in the market. Our farmers feed the soybean flour to their cattle, especially cows and buffalo, during their lactating period in order to get more milk.

Local methods of using soybeans in the human diet are: (a) Roasted soybeans mixed with roasted corn are eaten in the daily tiffin. (b) Roasted soybean cotyledons mixed with garlic, onion pieces, salt, and chilli are served as a cocktail. (c) Sprouted soybeans mixed with other sprouted pulses are used in vegetable soup. (d) Green soybean pods are eaten after steaming.

Nowadays the soybean eating habits have been changed by the people. Some have started preparing milk, yogurt, and the like from soybean. Rice cooked in soya milk with some coconut pieces is becoming popular. People have started using soybean flour in their baby food. (In our country more than half of the children die before the age of 5 due to protein malnutrition combined with disease.)

Since we have plenty of land for soybean cultivation, if we can use this land properly, besides fulfilling our domestic need we can also export the crop for foreign currency income. Realizing these facts our government has been taking a keen interest in cattle farming and poultry production projects. Up to now we have had neither a good pasture nor a balanced feed program. Some private agencies import fish meal and groundnut cake to meet the protein requirement of the poultry feed. Consequently, we are sending our currency outside since we have not been able to utilize our own resources. Our coordinated pulse improvement program is going to be established soon. Our soybean program is being included under this pulse improvement program. If the soybean program is launched successfully then we may be able to advance our soybean research most successfully.

M. PANDAY: Agriculture Botanist, Department of Agriculture, Education, and Research, Khumaltar, Lalilpur, Nepal.

Realizing the importance of soybean as food or feed, we started collecting local soybean varieties in 1971. We now have more than 200 indigenous soybeans in our collection. They were grown in 1971 in Khumal farm, Nepal, and observations were taken. These varieties are found to vary in seed coat color, leaf color, flower color, leaf pubescence, plant height, growth habit, and yield. While fly maggot and hairy cattle flies were found to be the serious pest, seedling blight and pustules were found in some areas. The incidence of disease varied from variety to variety. Nodule size and number were also found to vary from variety to variety.

Among these indigenous collections, we selected two brown varieties. These varieties can be harvested in 100 days. Their height is medium and protein content was found to be 50 percent. Their yield was calculated to be 42 and 43 q/ha. Some bacterial pustules were found in these varieties in the late harvesting stage but, since the incidence of pustule was very late, no significant reduction in yield was observed. The morphological compilation of all the above mentioned varieties will be completed after a few years.

DISCUSSION

S.M. FUNNAH: You mentioned that, in Nepal, maize and soyabeans are grown along the same row. Are these usually planted at the same time? If so, have you had problems with soybean varieties that can't tolerate shade?

M. PANDAY: The planting dates of the two crops may vary. However, the maize varieties used are of short stature. So we have not had any problems with shade.

S. MOUTIA: At what time is the soybean planted in the rice field?

PANDAY: The soybean is planted at the same time as the rice is transplanted during the month of July to August according to the mercy of rain.

Soybean Production in Nigeria

T.I. Ashaye, I.O.E. Asenime,
N.O. Afolabi, and
H.A. Van Rheenen

It has been rightly observed that prejudice and custom are among the factors that prevent people from adopting new crops of foods quickly. But Ochse et al. (9) had this to say on the future development of soybeans: "The remarkable progress made in the culture of soybean in the United States can be duplicated in many other countries provided due attention is paid to the selection of varieties adapted to the particular conditions of soil, climate, and length of day under which the crop is to be grown. They will form a valuable addition to the diet of any area and can serve as a source of raw material for a widely diversified chemical industry."

It appears the time has come when more attention should be paid to the production of soybean in Nigeria. At present, our greatest need is to stimulate interest in soybean production and use. When the Governments of the Federation show interest and are financially ready to back up a production campaign, it will not be difficult to find industries to consume the product. When this happens a great revolution can take place in Nigerian agriculture. This paper tries to put together data on the production and use of soybean in Nigeria.

Areas of Production

The main soybean-growing area in Nigeria is in the Southern Guinea Zone of Nigeria where a rainy season of 5 months or more discourages the cultivation of groundnuts.

Benue Province in Benue-Plateau State is a center of production, followed by the Abuja area in the North Western State and Southern Zaria Province in North Central State as minor production areas. The crop is produced in small holdings of 1 to 2 hectares per farmer, with an average yield of 600 to 800 kg/ha. All the areas of production and centers where research work is in progress are shown in Fig. 1.

By 1964 the highest tonnage of soybeans ever produced for export in Nigeria was 26,450 long tons from about 32,000 hectares (7). The production of soybeans and its market value is shown in Table 1.

Nigerian soybeans form a minor part of the total world production and most of the crop is sold to United Kingdom consumers. Italy, Hungary, and Western Germany are other markets for Nigerian soybeans. When compared with other world producers such as China and the United States of America, Nigerian produce is infinitesimal (0.05%). Between 1961 and 1968, world production has risen from 30 to 42 million tons with the United States of America producing more than half and China one-third of the world crop of soybean.

Nigeria soybean production has been erratic, due mainly to the fact that much of the production is left to the initiative of the farmers with little governmental control. Sharp declines between 1967 and 1969 may be mainly due to the Civil War, and the decline between 1970 and 1973 may be the result of a combination of factors such as lack of interest on the part of farmers and drought (Table 1).

Primary Uses of Soybean in Nigeria

Onochie (10) discussed the potential value of soybean as a protein supplement in Nigeria's diet. He observed that soybean has a higher total digestible nutrient percentage (91.99%) than cowpeas (79.52%) and therefore more metabolizable energy. Soybean also has a higher content of lysine (6.0 to 6.5%) than all other common vegetable protein sources. Soybean has never become popular in the Nigerian diet because it is very difficult to cook in traditional Nigerian ways, and it lacks the familiar taste. Onochie (10) noted that its use for the common "bean" recipes in Nigeria (olele and akara ball) is limited by its poor soaking and cooking qualities, lack of palatability, and change of color during cooking which renders it unattractive.

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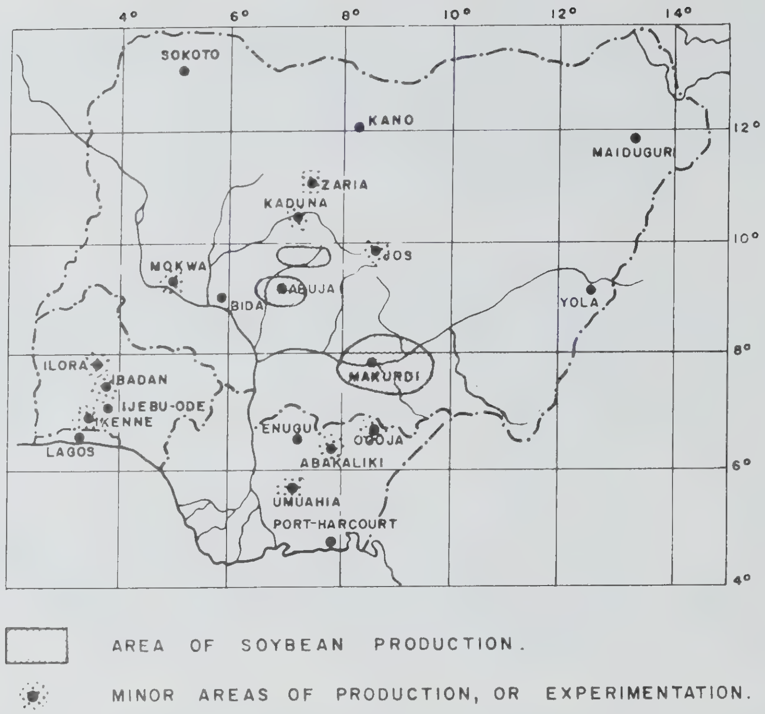

Fig. 1. Area of soybean production and experimentation in Nigeria.

Table 1. Soybean production and market value, 1957-1973.

Crop Season	Tonnage (long)	Value	Average F.O.B. price per ton
			k
1957-58	14,175	856,642.00	60.44
1958-59	3,169	229,650.00	76.55
1959-60	3,500	245,526.00	70.15
1960-61	13,750	949,896.00	69.00
1961-62	15,138	979,876.00	65.33
1962-63	26,450	1,828,034.00	69.08
1963-64	10,694	738,741.52	69.08
1964-65	15,617	1,038,530.50	66.50
1965-66	13,108	871,682.00	66.50
1966-67	18,155	1,252,695.00	69.00
1967-68	8,867	532,020.00	60.00
1968-69	4,539	328,714.38	72.42
1969-70	10,799	782,063.58	72.42
1970-71	4,806	328,730.40	68.40
1971-72	893	53,847.90	60.30
1972-73	234	15,022.80	64.20

For these reasons, most of the soybeans produced in Nigeria are exported as a cash crop, except for a few that are used for human consumption in some parts of the northern states. Yuwa (13) stated that the Gwarrin Genge around Diko have discovered that soybeans can be used for making "daddawa" in place of the usual locust bean. Also the Koros around Ija pound it into powder and use it in place of melon seed to thicken their soup. Recently, however, because of the prevalent kwashiorkor (acute protein deficiency syndrome) in many poor Nigerian children, there appears to be stimulated interest in the use of soybean for human food.

Incorporating Soybean into the Nigerian Dietary

There have been many suggested methods of utilizing soybeans for human consumption in Nigeria. Onochie (10) suggested that the use of soybean in the Nigerian menu can be improved by mixing it with the more desirable cowpeas paste for "olele" and "akara," by using it to fortify wheat flour for bread, or by making it into soybean milk. This soybean milk can then be processed into traditional foods such as kosai, alele, panke, and wara in the northern states of Nigeria or akara ball, moi-moi, and puff-puff in the southern states of Nigeria, with acceptable taste.

Recently, protein-enriched pap (soy-ogi) has been developed by the Federal Institute of Industrial Research (1). This is made by mixing soybean flour with corn flour and adding sugar for taste. Soy-ogi is meant for cheap baby food and so replaces costly dried skim milk. From test results, soy-ogi appeared to be well accepted by children. If the product is not expensive this may be the first step toward large-scale use of soybean for human consumption in Nigeria. The present cost of frying oil and protein meal for livestock in Nigeria points to the great potential for industrial uses of this crop when grown in large quantities. The oil will supplement groundnut oil and the very rich soybean meal will be valuable to the Nigerian livestock industry.

Varieties

Until recently, little attention was paid to soybean research in the southern states of Nigeria because most people did not recognize the nutritional value of soybeans for human consumption or their multi-industrial value. In the northern states, where most of the export crop of soybean comes from, attention has been paid to variety development. Gowen (5) observed that, in variety trials carried out in 1964, the collections from the United States exhibited striking differences in yield, plant maturity, plant size, pod shattering, standing ability, and disease resistance. In Northern State of Nigeria, the variety Malayan, the standard recommendation for all soybean growing areas (8), has been partly replaced by varieties such as Bf-S/58, Hernon No. 107, II G-1-7, and II G-1-1. Variety improvement through breeding was reported by the Institute for Agricultural Research, Samaru (11). At Mokwa Agricultural Research Station, which forms part of the Institute for Agricultural Research, Samaru, crosses had been made between CNS and Malayan. In a bulk population program, selections were made that exceeded yields of the recommended varieties in subsequent trials by about 40 percent. At the International Institute of Tropical Agriculture (IITA) in Ibadan, a soybean breeding program was started in 1970 and work has continued since then.

Fertilizer requirement for soybean in the northern states of Nigeria has been investigated. Super-phosphate has been found to be the best phosphorus fertilizer for soybean and, provided sulfur is not limiting, nitrogen fixation will occur. No response to potash has been found.

Regional Trials

Active research work in soybean started in eastern Nigeria in 1965 but was discontinued from 1968 to 1971 (3). Research attention was focused on variety trials. Most of the varieties tested were the local, low-yielding types, and yield results were generally low.

Research work in soybean in Western State has been inconsistent but has been given more attention since 1969. The period 1969-1971 was used for collection and multiplication of seeds. Variety trials started in 1972 have continued until the present.

Variety trials were carried out at Mokwa Agricultural Research Station and about five other locations in the northern states of Nigeria, which resulted in the recommendation of new varieties.

With the foundation of the IITA in Ibadan, more varieties became available for trial and breeding and agronomic work are in progress there.

Research and Production

Average yield of the commercial soybean varieties on a farmer's farm is 400 to 800 kg/ha of threshed grains (13). Low yields have been attributed to poor maintenance.

Results from experimental plots from the Federal Agricultural Research Stations at Bende and Umudike, the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, and the International Institute of Tropical Agriculture, Ibadan, showed high potentials

for soybean yield. Some exotic varieties such as Bossier, Hardee, CES 407, CES 486 and Improved Pelican yielded over 1,800 kg/ha with Bossier leading with 3,389 kg/ha at Bende, 3,246 kg/ha at IITA, 2,646 kg/ha at Ikenne, and 2,164 kg/ha at Moor Plantation.

Trial results from the northern states showed satisfactory results (11). At Mokwa, yields of well over 2,000 kg/ha were obtained. Experiments at Ganye and Jalingo yielded well. The variety Jackson gave the best yield at Jalingo with 2,162 kg/ha. The variety Bossier has been tested at Mokwa but gave disappointing results. However, in the south the prospects look very good for introducing Bossier as the best adapted variety (6).

Future Outlook

From the projected figures for 1972 to 1980 for Benue-Plateau State, it is estimated that area under soybean will rise from 36,951 hectares in 1972 to 40,405 hectares in 1980. This is an increase of 1 percent per year. Rise in seed production is estimated at about 2.5 percent per year, from 10,266 long tons in 1972 to 12,629 in 1980. This is a very conservative projection. Considering the stimulated interest in other parts of the country, by 1980 a larger area of land from the southern rain forest will have been devoted to soybean growing. With the introduction of high-yielding varieties and an increased knowledge of soybean culture, coupled with the awareness of its industrial potentials and its role in human nutrition, it may be assumed that Nigeria has the factors that are likely to stimulate increased production of this crop. In Benue-Plateau State, for example, a feasibility study was carried out on vegetable oil seeds processing. It was established that soybean was one of the oil seed crops that has great potential (12). It is not unlikely therefore that Nigeria may turn out to be a major producer in the future.

REFERENCES

1. Akinrele, I.A. et al. 1970. The development of soy-ogi, a corn-based complete-protein food. Research Report, Federal Industrial Research Institute. Oshodi, Lagos.
2. Benue-Plateau Ministry of Natural Resources. 1972. Estimated potential acreage and crop production in Benue-Plateau State 1972-1980. Ministry of Natural Resources (Planning Division) Jos.
3. Ene, L.S.O. 1973. A potential for soybean production in parts of the eastern states of Nigeria. Conf. paper. Annual Conference, Agricultural Society of Nigeria.
4. Food and Agriculture Organization. 1958. Legumes in agriculture and human nutrition in Africa. Rpt. Tech. Meeting. United Nations FAO/CCTA. Bukavu, Belgian Congo. November 1958.
5. Gowen, F.A. 1965. USAID final report, legume breeding program. Ministry of Agriculture and Natural Resources. Moor Plantation, Ibadan.
6. International Institute of Tropical Agriculture. 1973. Grain legume improvement program report. International Institute of Tropical Agriculture. Ibadan, Nigeria.
7. Nigeria Produce Marketing Company. 1964. Annual report. Nigeria Produce Marketing Company, Lagos.
8. Northern Nigeria Ministry of Agriculture. 1967. Guide to the production of soybeans. Ext. Guide No. 3. Northern Nigeria Ministry of Agriculture.
9. Ochse, M.J., J.R. Sonie, M.J. Dijkman, and C. Wehburd. 1961. Tropical and subtropical agriculture. Vol. 2, p. 1075.
10. Onochie, B.E. 1965. The potential value of soybean as a protein supplement in Nigerian diet. Proc. 3rd Ann. Conf. Agric. Soc. of Nigeria 4:43-45.
11. Samaru Institute for Agricultural Research. 1968. Annual report, 1967-68. Institute for Agricultural Research. Samaru, Nigeria.
12. Skoup and Company, Ltd. 1973. Vegetable oilseeds processing: a feasibility report. Benue-Plateau State Government.
13. Yuwa, J.A. Introduction of soybeans into Abuja. Samaru Agr. Newsletter 5(63-64): 100-101.

Soya Beans in Rhodesia

J.R. Tattersfield

Soya beans have, until now, played a minor role in the agricultural economy of Rhodesia. Production has been confined to commercial farms. Farmers of communal land have not produced soya beans to any extent, preferring to grow groundnuts, field beans, and cowpeas as edible legume seeds both for home use and for sale.

Soya beans can be grown successfully as a summer crop in rotation with irrigated winter wheat. Timing of the two crops is very satisfactory, soya beans occupying the land from late November to early April and wheat from early May until late October. The same machinery can be used for both crops and the irrigation necessary for wheat is also available for soya beans if rainfall is inadequate, thus ensuring high yields. As to fertility, the crops are complementary; soil nitrogen is enhanced somewhat by soya beans for use by wheat and, after heavily fertilized wheat, residual phosphate and potash can sustain the soya beans.

Soya beans also rotate well with maize and cotton. Benefits from preceding maize and cotton with soya beans include residual nitrogen, easy ploughing and soil moisture conservation, good tilth, ability to plant maize and cotton early, more flexibility with chemical weed control systems, and better utilization of labor and machinery by spreading peak demands. Although these are real benefits, economic considerations of costs and prices will be the main factors determining the popularity of soya beans compared with the other crops. Under present conditions, given good management, the profitability of maize and soya beans appear to be similar.

Yields of soya beans have until recently been disappointingly low, but with better varieties, better growing methods, and favorable prices, an improvement has been noted (Table 1). National average yields are usually below those expected by efficient producers. Farm yields of soya beans of 2,700 kg/ha are being achieved by a number of proficient growers and field yields as high as 4,400 kg/ha have been recorded. Recently, in variety trials, yields of 5,500 kg/ha were achieved. The indications are, therefore, that with the general application of good management practices and a satisfactory cost/price relationship, a marked improvement in the national average yield should occur.

RESEARCH

In the late 1950s it was considered that soya beans could play an important role in Rhodesian agriculture. At that time yields and prices were low but it was anticipated that research could lead to increased yields and that the demand for such a valuable food crop would inevitably rise. To increase yields, a research program was initiated involving various disciplines in the Department of Research and Specialist Services. Some soya bean research has also been conducted at the University of Rhodesia in the fields of plant physiology and microbiology, and the Department of Conservation and Extension has studied mechanization problems. A brief account of the research to date, and some key references of published work are given below.

Breeding

The first soya bean breeding in Rhodesia occurred in the 1920s and 1930s, resulting in release of a number of "Hernon" strains (1, 9). A second and much larger program was started in 1963 (13) which is now well established and to which the comments below apply.

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Table 1. Yields and prices of maize and soya beans, Rhodesia, 1966-1974 (commercial farm statistical returns).

Harvest year	Maize kg/ha	Maize Gross return[a/] ($/ha)	Soya beans kg/ha	Soya beans Gross returns[b/] ($/ha)	Ratio of maize to soya bean yields	Ratio of maize to soya bean gross returns
1966	3,318	115	448	25	7.4 : 1	4.6 : 1
1967	4,506	149	1,009	55	4.5 : 1	2.7 : 1
1968	2,354	85	471	41	5.0 : 1	2.1 : 1
1969	4,640	191	1,300	114	3.6 : 1	1.7 : 1
1970	3,251	129	695	61	4.7 : 1	2.1 : 1
1971	5,100	169	1,140	100	4.5 : 1	1.7 : 1
1972	5,631	225	1,591	123	3.5 : 1	1.8 : 1
1973	2,830	113	1,067	123	2.7 : 1	0.9 : 1
1974	6,350[a/]	255	1,700[a/]	196	3.7 : 1	1.3 : 1

a/ Estimated.
b/ Based on prices paid by the Grain Marketing Board in Rhodesian dollars.

The main plant breeding objectives are:

1. To increase seed yields, and 2. to select plants adaptable to summer day-lengths. Rhodesia lies between latitudes 16°S and 22°S and has relatively short day-lengths compared with the major regions of soya bean production. Many genotypes introduced from higher latitudes have flowered very quickly and been of small stature and low yield. Adapted genotypes have been introduced from South Africa, Brazil and southern United States.

3. To select plants of suitable maturity. The rainy period is about 4½ months in the major cropping areas; varieties must therefore mature within this period.

4. To develop good agronomic characteristics that will enable efficient combine-harvesting. These are: (a) resistance to pod shattering, (b) resistance to lodging, and (c) a pod clearance of at least 10 cm under good growing conditions.

5. Good physical and chemical seed quality.

6. Resistance to disease. Diseases are not at present a serious problem. The only ones of general occurrence are bacterial blight (*Pseudomonas glycinea*) and purple seed stain (*Cercospora kikuchii*).

The program is based at Salisbury Research Station (latitude 17° 48'S, altitude 1,506 m) but variety testing takes place at as many as 14 sites covering the potential growing areas. Initially progress depended on introduced material but artificial hybridization and selection using pedigree and modified pedigree methods now gives rise to a large number of pure lines for testing and, where appropriate, for release of seed.

Since 1963, three varieties have been released for commercial use:

1. Rhosa (12), introduced as a breeder's line from South Africa. Suitable for all areas of production in Rhodesia with good yield potential and reasonably satisfactory agronomic characteristics.

2. Bragg (14), introduced from the United States. Bragg was specifically released for production in low altitude areas below 1,000 m under irrigation where it outyields Rhosa.

3. Orbi (6) was bred at Salisbury Research Station and released in 1973. In areas above 1,000 m altitude its yield has exceeded that of Rhosa; below 1,000 m it has produced yields similar to Bragg in a limited number of trials. Oribi has good resistance to shattering and lodging.

Release of these varieties has increased yield potentials markedly. Hernon 147 was the highest-yielding variety prior to the more recent releases. Based on the results of numerous variety trials, if the yield of Hernon 147 = 100 percent than Rhosa was 126 percent and Oribi was 140 percent. In trials at low altitudes, the yield of Bragg exceeded that of Rhosa by 12 percent.

Rhizobium Inoculants

Work with a number of legume species showed that it was vital to have available Rhizobium inoculant to ensure good nodulation under Rhodesian conditions. To achieve this, a laboratory was established in 1958 to collect, test, and identify efficient Rhizobium strains, and an inoculant factory was established in 1962 to produce inoculants for commercial use. Both facilities were established at Grasslands Research Station, Marandellas, where they still operate.

Soya bean was one of the legumes catered for. Corby (3) showed that there were large differences in the efficiency of *Rhizobium japonicum* strains. Some strains were found to be very effective, supplying, through symbiosis, the entire nitrogen requirements of the crop, even on soils of low nitrogen status.

Investigations also showed that there could be considerable variety x Rhizobium strain interaction (5). Some strains produced very effective nodulation on some soya bean varieties but little or no nodulation on others. Thus strains had to be found that were compatible with all the commercially grown varieties. This was achieved and commercial inoculants were produced. These were, and still are, cultured on agar in glass bottles, single strains to a bottle. Three strains are sold to growers who are advised to mix the three when preparing to inoculate seed.

Peat-based inoculants sold in plastic containers have a number of advantages over agar cultures. Local peat was found unsuitable but Corby (4) has perfected a method using a neutral organic earth (made by rotting down maize cobs) as a base. Future commercial inoculants will be produced this way.

Soils in Rhodesia apparently do not naturally contain *R. japonicum* populations that will produce effective nodulation with soya beans (8). Thus where the crop is grown for the first time, inoculation is essential. After an inoculated crop was grown on a sandy soil, *R. japonicum* was found after five years (8). In both red loam and course sandy soils, however, the population decreased rapidly during the dry season, and even after one year the population level appeared to be inadequate to obtain optimum nodulation. In view of these findings and the cheapness of inoculation (approximately $2/ha) growers are advised to inoculate soya bean seed, even though a well nodulated crop was grown recently on the land to be planted.

Fertilizers

The amount of fertilizer required by soya beans depends mainly on the available nutrient status of the soil. For this reason soil analysis is widely used as a guide to recommendations. The amount of phosphate and potash recommended is about two-thirds of that recommended for maize. As soya beans often follow heavily fertilized wheat and maize, the amount required rarely exceeds 50 kg/ha of P_2O_5 and 30 kg/ha of K_2O.

Experiments have been conducted with nitrogen on both light and heavy textured soils. When the soya beans were inoculated with effective strains of *Rhizobium*, applying nitrogen at planting did not increase seed yields. Where a dressing of 48 kg/ha of N was applied at planting, nodulation was reduced by 32 percent. In light of this evidence, only very small starter dressings of nitrogen are recommended where heavy crops of straw have been ploughed in; none is recommended where a negative nitrogen phase is not expected.

The effect of applying lime prior to planting soya beans has been studied on soils of differing pH. These experiments have shown that yield responses to liming can be expected when the soil pH (calcium chloride basis) is below 5.5.

Weed Control

The biology of weeds and their control in field crops is studied by the Weed Research Team at Henderson Research Station, Mazoe (15). Weeds in soya beans can be controlled mechanically. A typical program is to disc harrow prior to planting, rotary hoe at emergence and if necessary until the crop is about 15 cm tall, then inter-row cultivate, preferably with a steerage hoe, two or three times. Problems arise on heavier textured soils during persistent wet weather and a number of growers prefer to use herbicides for weed control.

Where soya beans are grown, both grass and broad-leafed weeds are likely to be found. The grass weeds include *Eleusine indica* and sometimes species of *Brachiaria, Cyperus* and *Panicum*. The broad-leafed weeds are more numerous and include *Acanthospermum hispidum, Ageratum conyzoides, Amaranthus* spp., *Bidens* spp., *Chenopodium album, Galinsoga parviflora, Leucas martinicensis, Nicandra physaloides*, and *Tagetes minuta*.

Recommendations for control of these weeds have been published by Richards (10). For efficient control of the wide range of weeds, two herbicides are usually recommended together--one mainly to kill grasses, the other, broad-leafed weeds. The grass killers include Alachlor, Nitralin, and Trifluralin; those for killing broad-leafed weeds include Fluorodifen, Linuron, Naptalam + DNBP and Terbutryne. Tank mixes of Alachlor and the broad-leaf killers can be used as preemergence or emergence applications. Nitralin and Trifluralin must be incorporated prior to planting and the broad-leaf killers must be applied separately.

Agronomy

Aspects of soya bean agronomy that have been investigated are the response of varieties to planting dates, plant populations, and row spacings. In a four-year study at Salisbury Research Station, it was found that the early-maturing variety Rhosa, which matures at Salisbury in 125 days and grows about 90 cm tall, responded differently than Hernon 147 which matures in 150 days and grows to more than 120 cm. As Rhosa is the main commercial variety its performance in this study is summarized below.

1. Planting with the early rains in mid-late November gave better yields than when planting was delayed by 3 weeks. This is understandable as soya beans are susceptible to moisture stress during seed development (11) and late plantings may develop their seed when the rains have ceased and soil moisture reserves are depleted.

2. Seed yields increased up to a plant population of 445,000 plants/ha. Yields did not increase with thicker sowing but there was an increase in the amount of lodging.

3. Yields were greater in rows 50 cm apart than in 75 cm rows. This effect was obtained at all the populations tested between 148,000 and 592,000 plants/ha. The mean yield increase for the closer rows was only 161 kg/ha and the decision to use close rows must depend mainly on the ease and cost of weed control.

Entomology

A number of insect pests may attack soya beans, the most serious being semilooper caterpillars, which are the larvae of *Plusia* spp. These larvae damage the crop by feeding on the foliage and, in some cases, they may also chew into developing pods. Studies are being conducted on the biology of *Plusia* spp., prediction of outbreaks, and control measures. Egg laying usually starts at the end of December and may continue in waves until March. The intensity of egg laying appears to be negatively correlated with the incidence of rain in September.

Plusia activity can be detected by the presence of the moths caught in light traps. When large numbers of these are caught, radio warnings are broadcast. Damage can be avoided if control measures are applied before larvae commence extensive feeding. The timing of insecticide applications is greatly improved by regular scouting of the crop for the presence of eggs and larvae. Insecticides are then applied when the larvae are very small, before the third instar.

Control measures rely on the use of insecticides. The most common of the species, *P. orichalcea*, can be killed with a number of insecticides including DDT, monocrotophos, endosulfan, trichlorfan, malathion, and carbaryl. DDT is very effective and relatively cheap but its use is discouraged due to contamination problems. Recent studies have shown no DDT contamination of soya bean seed when the crop was sprayed twice during the season. DDT residues were found, however, on the stems and pods, which were considered unsuitable for livestock feeding.

Cases have been found in the field where a nuclear polyhedral virus has rapidly destroyed a dense population of *Plusia*. This virus may have general use as a control measure but more information is required on method of collection, storage, method of application, and rate and reliability of its spread under different environmental conditions.

Plant Physiology

Growth studies have been conducted under field and greenhouse conditions. Field studies measured growth of varieties at different spacings. Data on growth parameters, pod distribution, and apportionment of dry matter were obtained. Two points of interest were: (a) petioles account for 25 percent of the structural dry matter, and (b) dry matter accumulation in the seed is confined to the last 3 to 4 weeks of the plant's life.

In greenhouse studies a complete analysis of different varieties was conducted in both winter and summer. Data included specific leaf areas, photosynthetic rates per unit leaf area, carbon content of all components, and carbon apportionment from leaves to other parts of the plant. Pod abortion was correlated with leaf areas and was greatest at maximum plant dry weight. Pod abortion was an important component of potential yield loss, and it was greatest in profusely flowering varieties.

Future work will concentrate on studying temperature and light effects in both the photo and nicto phases. Whole populations will be studied, using gas analysis in a growth chamber illuminated by sunlight.

Studies of seed viability showed that in hot, low-altitude areas, a large proportion of the seed was nonviable at maturity and the live seed that was harvested became nonviable in normal shed storage within a few months. In such areas seed cannot be produced and must be obtained from cooler areas. Viability was also markedly reduced with repeated wetting and drying, emphasizing the need to harvest seed as soon as possible to minimize rain damage.

Mechanization

Some aspects of planting and harvesting have been examined. In order to ensure regular germination and to elevate plants as an aid to harvest, a system of planting is being developed on corrugations. Seed is sown at shallow depth into the top of 5 to 7.5 cm high corrugations along with a limited quantity of water to ensure good germination if the soil is drying out. The amount of water required is about 2,000 liters/ha.

Another planting system is being studied with zero tillage when soya beans follow wheat. Planting units are being tested and developed for this method which, if successful, will reduce establishment costs and protect the soil against run-off and erosion.

Harvesting studies to date have mainly measured the performance of different makes of combines and threshing machines with soya beans (7). Emphasis has been on rates of work, losses, and grade of the threshed seed.

EXTENSION

Very useful knowledge has now been obtained on the techniques for growing soya beans from both the research program and the experience of growers. With a new crop especially, dissemination of information and the availability of specialist advice is very important. To assist with this problem a specialist oilseeds extension officer from the Department of Conservation and Extension is based at Salisbury Research Station. He supplies a vital link between research and the producers. In addition an Oilseeds Handbook has recently been published (2), which contains advice on all aspects of both soya bean and groundnut production. As it is in loose leaf form, it can easily be amended.

REFERENCES

1. Arnold, H.C. 1941. Soyabeans, results of trials season 1940-41. Rhodesia Agr. J. 38(9):475-486.
2. Collett, W.E. 1973. Oilseeds handbook. Department of Conservation and Extension. Salisbury, Rhodesia.
3. Corby, H.D.L. 1967. Progress with the legume bacteria in Rhodesia. Proc. Grassld. Soc. South Afr. 2:75-81.
4. Corby, H.D.L. 1973. A method of making pure-culture, peat-type, legume inoculant, using a substitute for peat. In P.S. Nutman, ed., Symbiotic nitrogen fixation in plants. No. 7, I.B.P. Series (in press).
5. Corby, H.D.L., W.P.L. Sandmann, and J.R. Tattersfield. 1964. Differences in the symbiotic relationship between varieties of soyabean and strains of *Rhizobium japonicum*. Rhizobium News Letter 9:83-86.
6. Department of Research and Specialist Services. 1974. Release of "Oribi" soyabean. Rhodesia Agr. J. 71(5):129.
7. Jones, M.E. 1971. Field investigations into harvesting and threshing machinery for soyabeans. Rhodesian Farmer 42(1):11-15.
8. Nash, S.M., and O. Moerman. 1967. Inoculum potential of introduced *Rhizobium japonicum* in certain Rhodesian field soils. Rhod. Zamb. Mal. J. Agr. Res. 5:215-220.
9. Rattray, A. 1960. The soyabean in Rhodesia. Rhodesia Agr. J. 57(3):179-185.
10. Richards, P.V.M. 1973. Chemical weed control in Rhodesian crops. Rhodesia Agr. J. 70(6):148-155.
11. Tattersfield, J.R. 1966. The sensitivity of soyabeans (*Glycine max* L. Merrill) to lack of moisture during seed development. Rhod. Zamb. Mal. J. Agr. Res. 4:107-109.
12. Tattersfield, J.R. 1967. Release of a new soyabean variety--Rhosa. Rhodesia Agr. J. 64(2):25.
13. Tattersfield, J.R. 1968. Improvement of soyabeans in Rhodesia. 66th Ann. Cong. South African Assoc. for Advancement of Science. Lourenco Marques, Mocambique. July 1968.
14. Tattersfield, J.R. 1972. Release of soyabean variety--Bragg. Rhodesia Agr. J. 69(4):85.
15. Thomas, P.E.L. 1973. A review of weed research in Rhodesia. Rhodesia Agr. J. 70(6):138-139.

Soybeans in Rwanda

A. Camerman

Rwanda is a small, mountainous country located south of Uganda, east of Zaire, and west of Tanzania. It has a total area of 26,000 km^2 with a population of 3.5 million. Altitude ranges from 1,100 m to more than 4,000 m.

Soybeans were introduced into Rwanda by INEAC in the 1920s. Farmers started showing interest in soybeans in 1960. In 1969 production amounted to 550 ha and in 1973 there were 1,640 ha. The main reasons for such interest are:

1. Intensive extension work by the nutrition centers scattered around the country. These centers have demonstrated how to cultivate and how to prepare soybeans in the form of milk, cheese, and flour.
2. Soybeans are more resistant to diseases than beans (*Phaseolus vulgaris*), which are a basic staple of Rwandans.
3. Soybeans are ecologically plastic (flexible).

The most widespread variety is Palmetto from Colombia. The table below shows the yield of soybeans under experiment station and peasant farm conditions with and without inoculation.

	Average yield (kg/ha)	
	Without inoculation	With inoculation
Station	1,300	1,800-2,000
Peasant farm	750	1,400

Inoculation is very important. The research institute (ISAR) has shown that inoculation was equivalent to a fertilizer application of 50 to 100 kg of N/ha. In Rwanda, one unit of N cost 77 Rwandan francs in 1973 ($1 U.S. = 100 Rwandan francs). This is too expensive for the small farmer. ISAR is studying the possibility of building a small inoculum plant which could allow the sale of inoculum at a very low price to the farmer.

The government of Rwanda envisages building, by 1976, a polyvalent oil mill based mainly on peanuts and soybeans. As soon as the mill is completed, 5,000 ha could be put under soybeans.

Starting in 1975, ISAR hopes to cooperate with the International Soybean Program (INTSOY) in order to introduce new high-yielding varieties as soon as possible.

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Soybean in Saudi Arabia

M.Z. Jowana

Soybean is not presently grown in Saudi Arabia. In 1973 the Ministry of Agriculture and Water started field trials and observations to study the possibilities of growing this crop in some parts of the Kingdom.

The 1973 variety trials were conducted at four locations using six varieties from Taiwan: Kaohsiung No. 3, Wakashina, Tainung No. 4, NTU No. 5, Shih-Shih, and Permito.

Four varieties were planted at Uneizah on 6 October 1973 and were harvested on 14 January 1974. Yields in kg/ha were: Kaohsiung No. 3, 340; Wakashina, 115; Tainung No. 4, 174; and Shih-Shih, 193. All four varieties were affected by rust diseases.

At Qatif, Kaohsiung No. 3 and Wakashina were planted on 6 October 1973. Both varieties yielded very poor growth and empty pods. Results from plantings made at Gizan were not reported. All six of the Taiwan varieties were planted at Hofuf in early October 1973, which was out of season. Chlorosis was observed.

Fourteen varieties of soybean were planted in Aizan at 2-month intervals from December 1 to April 1 of the 1973-1974 season. An additional four varieties were planted in the October period. Experimental design was split plot with the sowing date the main plot and the varieties subplot. There were three replications for each of the 14 varieties. Plot size was 2 m, stands 1 to 4 rows 10 m long, spaced 50 cm apart. Seeds were planted 45 to a hill 25 cm apart and thinned 2 plants per hill at the proper time. Planting dates were October 1, December 1, February 1, and April 1. Yields have not yet been obtained.

In 1974, seeds for three variety trials, each with 15 varieties, were received from the International Soybean Program (INTSOY) at the University of Illinois. Planting locations are Jizan, Uneizah, and Dirab. Seeds of 10 varieties (8 lb each) have been obtained from the Delta Experiment Station in Stoneville, Mississippi. Varieties are Lee, Pickett 71, Dare, Cobb, Hutton, Bragg, Tracy, Forrest, Hampton 266A, and Hardee. The five last-named are among the varieties received from INTSOY. Also received from Mississippi were 2 lb each of Jupiter and Improved Pelican varieties. Planting locations are El-Kharj, 10 varieties, 4 lb each; Jizan, 10 varieties, 4 lb each and 2 varieties, 2 lb each.

DISCUSSION

A.M. CONJE: How are the soybean plantings doing in the Gizan area? We have not tried grouping soybean in Yemen and I thought that since the environmental conditions in Gizan are similar to the Trhama region in North Yemen, your results will be of great interest to us in Yemen.

M.Z. JOWANA: Soybean trials only started in Gizan in the season 1973-74. The yield was very low, but we think the promising varieties are: Wakashima, Kaosiung, and Bossier. The last sowing date is December 1.

M.Z. JOWANA: Director, Plant Production Division, Department of Research and Development, Ministry of Agriculture and Water, Riyadh, Saudi Arabia.

Soybeans in Sierra Leone

S.M. Funnah

As in many other developing countries, there is a protein shortage in Sierra Leone. Whole soybeans are an excellent source of protein, in both quantity and quality. About 40 percent of the total dry matter content of whole soybean is protein. Whole soybeans are also high in caloric value, containing about 20 percent fat. Thus if soybeans can be successfully grown in Sierra Leone, they would help reduce the present widespread calorie and protein shortage both in human diets and in livestock feed. In spite of the apparent advantage that soybeans possess, they are still not cultivated on a commercial scale in Sierra Leone. The total number of hectares under soybeans seems to be limited to the small area under field experiments.

However, with the identification of high-yielding cultivars, two factors may induce commercial soybean production in Sierra Leone. The first is the establishment of a number of poultry farms by private individuals. Second, the Sierra Leone Produce Marketing Board, which serves as the government's buying agent for agricultural produce, is interested in soybeans both for export and for local consumption.

Primary Use of Soybeans in Sierra Leone

Current soybean research in Sierra Leone has concentrated mainly on identifying high-yielding cultivars. No attempts have been made to find ways of processing soybeans for local uses. It does seem, however, that soybeans will have a place in livestock and poultry feeds in Sierra Leone, more so with the establishment of feedmills that are underused because of corn shortage.

In the rainy season, which is a time of food scarcity in Sierra Leone, some people could eat whole soybeans by boiling and preparing them as they would pigeon peas. Many Sierra Leoneans use imported soybean oil, soya sauce, and other soybean products. Thus when soybean production reaches a commercial level in Sierra Leone, if there are processing facilities, there is no doubt that consumption of soybean products will increase.

STATUS OF SOYBEAN RESEARCH IN SIERRA LEONE

Previous Work

Weibel (2) conducted three separate soybean yield trials on upland and river terrace soils, using 5 varieties imported from Illinois. He obtained yields ranging from 17 to 21 bu per acre. Kamara (1) tested 6 varieties of soybeans, with 2 inoculum levels under irrigation. The yields ranged from 1,984 to 2,562 kg/ha for the normal inoculation and from 2,127 to 3,035 kg/ha for the additional inoculation--not a significant difference. In June 1972, Kamara conducted another yield trial under rainfed conditions. Because of the low germination percentage, no meaningful data could be obtained from this trial. W.E. Taylor (personal communication, 1974) conducted some trials on storage conditions for soybeans. He found that, at low moisture content, storage in an air-conditioned room resulted in the highest germination percentage. In 1973, the Department of Agronomy at Njala University College started cooperating in the International Soybean Program (INTSOY) trials. The results that have so far been obtained under this program are reported below.

1973 INTSOY TRIAL

Materials and Methods

Twenty soybean varieties belonging to different maturity groups were obtained from the University of Illinois, Department of Agronomy. These varieties were grown under rainfed conditions, using a randomized complete block design with four replications. Each plot measured 6 m X 2.4 m. The 4 rows making up each plot were spaced 60 cm apart. The

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soybeans were grown on silty clay river terrace soils. Basic slag, at the rate of 1,200 kg/ha, was applied (broadcast) a week before planting. Potassium sulfate was applied at the rate of 160 kg/ha, broadcast. Just before planting, the seeds were treated with a commercial inoculant, Nitragin, using sugar solution as a sticker. The treated seeds were then immediately sown evenly, at a depth of 4 to 5 cm, and covered with soil. The plants were kept weed-free by hand weeding.

The data collected included days to emergence, stand after thinning, days to flower, plant height at maturity, canopy height, stand at maturity, lodging, shattering, and seed yield.

At harvest, the two middle rows, excluding the end plants, were cut at ground level and sun-dried for about two weeks. At threshing, the dried plants (with their pods attached) were put in jute bags and beaten with a stick, taking care not to cause undue damage to the beans. The broken pods and grains were then winnowed, and the weight of dry, clean seeds was recorded.

Results and Discussion

Of the 20 varieties used, only 11 had over 50 percent germination. The remaining 9 either did not germinate at all, or could not provide enough plants in the harvest area. Most of the 11 varieties that germinated did so about 5 days after planting.

Table 1 shows the results of the 1973 trial. Plant height ranged from 19 to 47 cm. The plants were generally shorter than when grown under U.S. conditions. Fifty percent bloom occurred 25 to 31 days after planting. Lodging occurred to a very small extent in the tallest variety, Improved Pelican.

There were highly significant differences in yields among varieties. The yields obtained ranged from 784 to 2,025 kg/ha. As in one previous trial (1), Improved Pelican proved to be the highest-yielding variety.

1974 INTSOY TRIAL

Materials and Methods

The 20 soybean varieties used in the 1973 trial were also grown in 1974. This trial was conducted under irrigation. A randomized complete block design with three replications was used. Each plot measured 1.2 m X 6 m with 4 rows in each plot spaced 30 cm apart.

Basic slag at the rate of 1,200 kg/ha was applied broadcast a week before planting. Potassium sulfate was applied at the rate of 160 kg/ha. As in the 1973 trial, the seeds were inoculated with commercial Nitragin prior to planting.

The data collected included days to flower, days to maturity, canopy height, plant height at maturity, shattering, lodging, seed yield, and seed weight. Harvesting and threshing were done as described for the 1973 trial.

Results and Discussion

Results of the 1974 INTSOY trial are shown in Table 2. Compared to the 1973 trial (grown under rainfed conditions), for a given variety, yields recorded for the 1974 trial were generally lower than those obtained in 1973. However, Improved Pelican again was the highest-yielding variety. A higher germination percentage was obtained in 1974 than in 1973 as evidenced by the data collected from all 20 varieties used. This was probably related to the storage conditions to which the two seed lots were subjected. In 1974, the seeds were planted a few days after they were received from INTSOY, whereas the 1973 seed lot was stored under room temperature for about three months prior to planting. The 1974 plants were generally shorter than those in 1973. This may have been related to the inadequate irrigation facilities and the higher population used in 1974. Except for a few varieties (e.g., Cutler 71), the days to flowering tended to remain constant.

PLANT PROTECTION

Diseases have not been a serious problem in experimental plots in Sierra Leone. So far, the only disease observed is bacterial wilt, caused by *Sclerotium rolfsii*. However, various leaf-mining insects have been reported to attack soybeans. The most serious of these is the common grasshopper (*Zonocerus variegatus*). Spraying with a weak solution of Agrocide has given some amount of control.

Table 1. Results from International Soybean Program (INTSOY) trial at Njala, Sierra Leone, 1973.

Variety[a]	Maturity group	Days to flower	Stand at harvest[b]	Height at maturity (cm)	Seed yield (kg/ha)
Coker Hampton	VIII	28	141	22	915
Improved Pelican	VIII	31	203	47	2,025
Bragg	VII	28	249	19	784
Semmes	VII	28	249	19	784
Davis	VI	29	148	21	1,120
Lee 68	VI	26	169	21	1,346
Picket 71	VI	27	209	23	877
Adelphia	III	25	123	23	988
Williams	III	25	148	32	1,406
Harosoy	II	25	140	31	1,411
Cutler 71	IV	25	221	33	1,077

a/ Planted September 15.
b/ Refers to the two middle rows.

Table 2. Results from International Soybean Program (INTSOY) trial at Njala, Sierra Leone, 1974.

Variety[a]	Maturity group	Days to flower	Stand at harvest[b]	Height at maturity (cm)	Days to maturity	Seed yield (kg/ha)
Coker Hampton	VIII	28	149	14	74	806
Improved Pelican	VIII	33	174	29	76	1,167
Bragg	VII	28	168	19	67	694
Semmes	VII	28	160	14	67	917
Davis	VI	31	145	17	84	889
Lee 68	VI	28	150	14	67	667
Picket 71	VI	28	147	15	66	528
Adelphia	III	32	159	17	68	722
Williams	III	32	148	16	68	660
Harosoy 63	II	28	144	19	67	417
Cutler 71	IV	33	143	30	69	1,110
Hutton	VIII	28	141	17	76	833
Dare	V	30	153	18	69	667
Hill	V	32	108	19	72	583
Bonus	IV	29	131	16	71	528
Clark 63	IV	28	146	23	71	889
Hark	I	28	147	16	65	639
Hardee	VII	31	133	16	77	639
Calland	III	28	128	22	75	917
Jupiter	IX	33	141	37	90	254

a/ Planted February 4.
b/ Refers to the two middle rows.

PRESENT OUTLOOK AND FUTURE WORK

Detailed agronomic work on soybeans in Sierra Leone has been meager at present, and is not yet a priority in the country. The present aim of the Soybean Research Project at Njala is to identify productive and adapted varieties and suitable management practices for commercial soybean production in Sierra Leone. An important management problem which needs urgent attention is storage. The longevity of soybeans, relative to other crop

seeds, is low. In order to obtain a higher germination percentage in the field, soybeans may have to be stored under cold conditions at a low moisture content.

Another problem is to come up with the optimum planting date. This problem is related to moisture availability during the growing period and the amount of sunshine required for drying the harvested crop. If cheaply constructed dryers are available, then the emphasis lies on moisture availability during the growing period. A date-of-planting experiment already in progress at Njala may be able to throw some light on this problem.

Developing ways to utilize soybeans within Sierra Leone appears to be another problem that needs careful consideration. Soybeans in various forms have been used as food by millions in the Far East for centuries. However, whole soybeans have not been generally accepted for human use in many other countries, including many of the developing nations. However, in the United States, the development of prototype foods has led to a higher use of soybeans by humans. In Sierra Leone, it seems as if a first step toward including soybeans in human diets is to use them as livestock and poultry feed. With help from food scientists and engineers, it may later be possible to diversify soybean products to include soybean oil which could be a suitable alternative to the oils and fats now used by Sierra Leoneans.

Finally, if soybeans are to be grown commercially in Sierra Leone, a reliable and cheap source of the appropriate inoculum is necessary. In the absence of a local source, valuable foreign exchange may have to be used to import the necessary inoculum.

Acknowledgments

The International Soybean Program (INTSOY) provided the seeds and the inoculant used in the variety trials and the Sierra Leone Produce Marketing Board gave financial support.

REFERENCES

1. Kamara, S.B. 1973. Preliminary soybean variety trials with two levels of inoculum in Sierra Leone. Sierra Leone Agr. J. 2:9-13.

2. Weibel, R.O. 1966, 1967. Soybean yield trials on upland and river terrace soils at Njala University College. Unpublished data.

DISCUSSION

A. ASSA: When do you plant and harvest soybeans in Sierra Leone?

S.M. FUNNAH: In 1973, planting took place on September 15 around the middle of the rainy season. The 1974 planting took place on February 5. Probably September-October are the optimum planting months--but planting date trials should prove or disprove this statement.

ASSA: What happened to the soybean seed imported by the Produce Marketing Board in early 1974?

FUNNAH: These seeds were going to be used to start commercial soybean production in Sierra Leone. However, because we the agronomists have advised SLPMB (Sierra Leone Produce Marketing Board) not to start such a project without knowing a lot more about soybeans, it appears they dropped the idea. The SLPMB is, in any case, currently supporting soybean research. I don't know, for sure, what happened to the seeds.

Soybean Cultivation in Sri Lanka: A Progress Report

H.M.E. Herath

From a nutritional point of view, soybeans are classed as "protective" foods and form an important component of the human diet, supplying essential proteins. Recent dietary surveys have indicated that the diet of the average person in Sri Lanka is deficient in these vital protective foods. This deficiency can be corrected to a large extent by an increased consumption of grain legumes. But, poor and irregular availability, resulting in comparatively high prices, has in the past placed most locally grown grain legumes beyond the reach of the average person in this country.

This is all the more regrettable because variation in soils and climate in Sri Lanka permits the successful cultivation of a wide range of pulses such as soybean in the different agro-climatic zones of the country. However, soybean cultivation in this country has until very recently remained in a relatively underdeveloped state. Except for a few sporadic attempts, their cultivation has been in the form of home-garden plots where subsistence rather than the market has been the orientation.

The reasons for such a situation are many and varied, but among them may be listed the following: nonavailability of dependable high-quality seed especially selected for suitability to local conditions, the fragmentary nature of information available on the techniques of cropping under local conditions, lack of a specialized extension service capable of advising soybean growers and looking after their needs, and, probably most important of all, the poor marketing arrangements available to growers, which has often resulted in an insufficient return on his capital to the farmer and uneconomical prices of grain legumes to the consumer and the processor.

Recently the development of the soybean processing industry and the knowledge of available foreign markets for soybean products have to a certain extent solved the problems of marketing and created the climate for increased soybean production. The government is planning to provide incentives to soybean growers in the form of subsidies and loans. The government's Five Year Plan has also emphasized the importance of earning foreign exchange. The problems now seem to center around the inadequacy of production to meet foreign demand and the increasing local market, and also on the need to reduce production cost. A severe shortage of qualified and trained staff in the field of agriculture at present keeps in abeyance the initiation of new lines of work, including that on soybean. The present program is aimed at rectifying the deficiencies of existing programs of research and extension in soybean cultivation, as functions of the Department of Agriculture.

CURRENT STATUS OF SOYBEAN PRODUCTION

In the past, research on soybeans received scant attention in the Department of Agriculture and had a low priority compared with research on rice and other food crops.

Soybean was first introduced to Sri Lanka in 1947. Various trials were carried out in the dry zone and hill country but, because soybean was unable to compete with other pulses, little attention was given to it.

The government felt that the problem of achieving self-sufficiency in pulses was greater than with other subsidiary food crops, first because of the very large cultivated area annually required for self-sufficiency in all pulses, and second because only a few of the imported pulses have been successfully grown in the country. But time has proved that most of the rice-growing areas have sufficient residual moisture in the fields to support a short-duration crop following rice.

H.M.E. HERATH: Coordinator, Soybean Program, Central Agricultural Research Institute, Peradeniya, Sri Lanka (Ceylon).

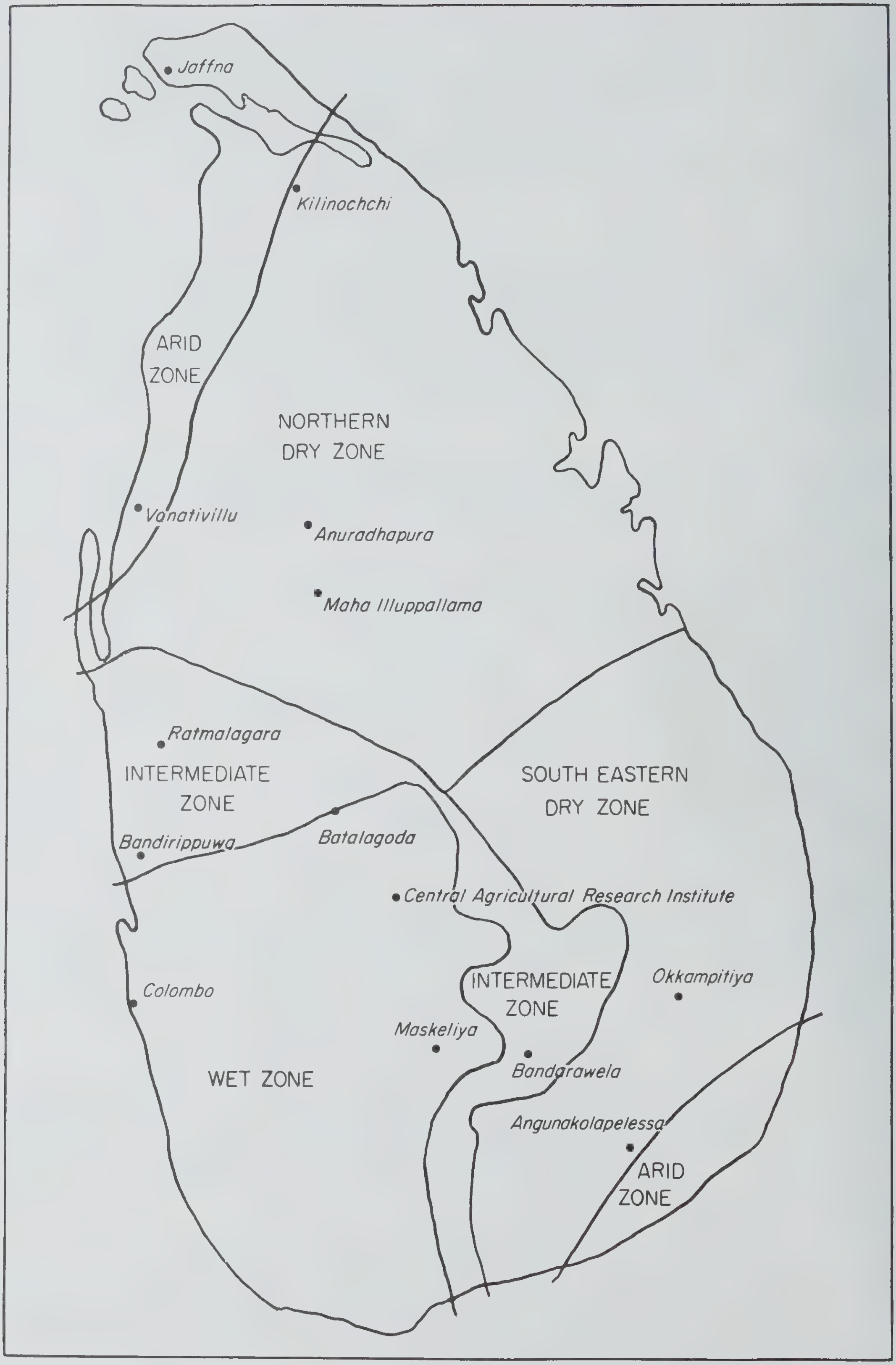

Fig. 1. General agro-climatic zones of Sri Lanka and International Soybean Program (INTSOY) locations for 1974.

Failure of attempts to grow soybeans in the past has led to a general belief that they cannot be grown in Sri Lanka in sufficient quantities for commercial exploitation. In 1973, however, with the introduction of the first International Soybean Program (INTSOY) kits to Sri Lanka, it has been found that soybean does very well in most locations, and research since then has shown that there is a possibility of intercropping certain plantations with soybean. This not only will enrich the soil with nitrogen, but will serve as an additional source of much needed protein in the diet.

Recent findings show that even rice areas now growing only one crop in maha season (October-February) can grow a soybean crop in time to vacate the land for rice.

The amount of irrigation required to cultivate 1 acre of rice can be used to grow 3 to 4 acres of soybean in some areas of the dry zone where facilities are available for year-round cropping.

Consumption Patterns

Soybean is mainly consumed in Sri Lanka as a substitute for lentils. There is also an increasing demand for soy flour used in a mixture with rice and wheat flour. Pilot projects for the production of soy milk, soy oil, and blending of cowmilk for spray-drying have been initiated. Since there is a severe shortage of animal feed, soybean and its by-products are being increasingly used in the livestock industry.

Extent of Cultivation

The acreage under soybean is increasing annually, from a few acres in 1971 to nearly 5,000 acres in 1974. This is an appreciable increase, considering that a traditional grain legume such as green gram occupies an area of only 15,000 acres. The bulk of this soybean crop is solely a seed increase program. It is hoped that by the end of the present season Sri Lanka will have sufficient seed to embark on a national soybean production program.

To popularize the cultivation of soybean, the Extension Division of the State Department of Agriculture has issued for this year nearly 10,000 production kits of the more popular varieties such as Bragg, PB-1, and Tainung(r)-1, free of charge to prospective soybean growers. The produce from these plantings forms the basis for local seed consumption in the rural areas. Farmer and consumer acceptance have been encouraging. Yields of up to 2,000 lb per acre have been recorded under farm conditions.

RESEARCH

A highly specific and well organized soybean research program was initiated in 1973 and the results of these investigations are discussed here. The program consisted mainly of experiments dealing with varietal testing. These included evaluation of already existing varieties in Sri Lanka as well as participation in the International Soybean Program (INTSOY) varietal trials in collaboration with the University of Illinois. Other investigations consisted of fertilizer, plant spacing, herbicide, nodulation, and seed storage experiments. The trials were conducted in four locations, three of them in the dry zone of the island but having different agro-climatic characteristics, and during two seasons of the year, i.e., yala season (April-September) and maha season (October-February).

The coordinated varietal trial carried out in 1973 produced high yields of 3,000 to 4,000 kg/ha with the Asian variety Pb-1, while American varieties such as Hardee, Lee, Bragg, and Improved Pelican showed similar yield potential. The INTSOY varietal trial has so far been conducted for three seasons, two yala and one maha (Tables 2 and 3).

Data for two yala seasons (Tables 2 and 4) for the wet zone location recorded high yields for Hardee (3,145, 3,226, 3,986 kg/ha) while showing good yield potential for Davis, Improved Pelican, Calland, Pickett 71, Hampton 266A, Pb-1, and S.J.-2. Hardee at 105 days obtained a yield of 3,986 kg/ha.

Varieties Hardee, Jupiter, and Harosoy 63 did well in the dry zone locations.

In the wet zone location all the varieties matured earlier in the maha season trial. Semmes gave the highest yield followed by Davis, Lee 68, Bragg, and Hardee (Table 3). The dry zone stations recorded highest yields for Williams, Hampton 266A, and Hardee for this season.

Table 1. Soybean yields (kg/ha), coordinated varietal trial, yala season 1973, at four locations in Sri Lanka.

Variety	Gannoruwa	Maha Illuppallama	Peradeniya	Alutharama
Improved Pelican	3,774	1,662	3,883	3,364
Hardee	3,852	2,029	--	4,008
Taichung E-32	3,194	1,540	2,125	3,049
Lee	3,840	2,451	--	3,278
Pb-1	4,053	3,181	3,849	3,019
Bragg	3,709	2,317	--	3,410
Taichung -26	3,326	1,460	2,365	3,094
S.J.-2	3,613	1,485	2,263	2,592
T.K.-5	3,577	1,553	2,008	3,533
Tainung(R)-1	3,470	1,626	2,311	3,409
LSD (0.05)	366			
C.V.	6.29			
Altitude, m	457.2	137.7	266	30
Latitude	9^{o}N	$8^{o}5$ N	$7^{o}30$ N	7^{o}N
Soil type	clay loam	sandy clay loam	sandy loam	clay
Soil pH	5.7	5.8	--	--

Table 2. International Soybean Program (INTSOY) variety evaluation experiment yields (kg/ha), yala season 1973, at four locations in Sri Lanka.

Variety	Gannoruwa	Maha Illuppallama	Alutharama	Angunukulapalessa
Hardee	3,987.5	---	3,536.5	1,207.3
Calland	3,780.3	--	3,150.6	1,995.0
Davis	3,653.2	2,262.5	2,971.4	2,134.6
Pickett 71	3,552.4	2,392.6	2,593.0	2,135.4
Hampton 266A	3,534.5	2,297.1	2,912.2	2,785.6
Improved Pelican	3,488.2	2,035.0	2,445.1	2,298.4
Jupiter	3,456.1	2,831.8	1,098.6	--
Williams	3,454.0	2,278.8	2,212.9	2,657.2
Semmes	3,301.5	2,091.7	3,192.7	2,684.3
Clark 63	3,272.3	2,193.8	3,010.6	2,003.7
Adelphia	3,234.4	2,280.5	2,009.6	2,901.0
Dare	3,181.9	2,210.4	2,353.4	2,566.8
Cutler 71	3,167.3	--	3,007.7	2,133.3
Lee 68	3,155.6	2,217.5	3,390.3	2,126.7
Harosoy 63	3,043.5	1,850.0	2,832.6	3,048.9
Bragg	2,984.8	2,348.8	3,433.6	1,988.7
Hill	2,943.1	1,884.1	2,374.6	807.2
Hutton	2,926.4	2,229.2	3,417.4	594.7
Bonus	2,879.7	2,201.3	2m772.6	1,719.1
Hark	2,503.0	--	1,746.6	2,380.1
Grand mean	3,275.0	2,225.3	2,723.1	2,114.1
SE	193.6	103.9	281.1	377.9
C.V.	11.8	9.6	20.7	35.8
LSD (0.05)	547.5	293.9	795.2	1,069.0

Table 3. Interntional Soybean Program (INTSOY) variety evaluation experiment yields (kg/ha) maha season 1973-1974, at five locations in Sri Lanka.

Variety	Gannoruwa	Maha Illuppallama	Alutharama	Ratmalagara	Bandarawela
Semmes	2,268.8	2,924.3	1,530.3	452.6	1,083.6
Davis	2,172.5	2,927.7	1,356.1	435.9	1,177.3
Lee 68	2,170.4	2,516.3	1,364.0	430.1	1,177.3
Bragg	2,166.7	2,980.2	1,346.9	320.9	520.9
Hardee	2,110.0	3,249.8	1,936.2	534.3	1,239.8
Pickett-71	2,097.5	2,485.9	1,472.4	452.2	1,166.9
Hampton 266A	2,026.2	3,499.4	1,539.5	502.2	1,135.6
S.J.-2	1,935.8	2,654.3	1,737.0	431.8	1,396.1
Tainung R-1	1,933.3	2,606.4	1,209.4	255.5	864.8
Calland	1,922.5	2,272.5	1,470.3	420.5	854.3
Hutton	1,896,2	2,424.2	1,545.3	378.0	1,010.6
Harosoy 63	1,863.9	2,290.5	1,346.9	456.8	791.8
Improved Pelican	1,859.5	2,402.1	1,737.8	464.0	916.9
T.K.-5	1,824.9	2,449.2	1,274.4	254.2	1,104.4
Williams	1,785.8	4,003.3	1,541.6	474.7	1,312.8
Clark-63	1,652.0	2,625.9	1,313.6	460.9	1,198.2
Pb-1	1,618.2	3,104.0	1,379.4	496.8	469.0
Adelphia	1,575.3	2,600.9	1,209.8	474.3	1,041.9
Hark	1,482.4	1,724.9	969.8	296.7	604.3
Jupiter	1,421.5	2,217.1	1,757.9	257.6	1,823.3
Grand mean	1,889.1	2,698.0	1,451.9	412.5	1,044.5
SE	135.5	214.4	135.8	49.5	106.9
C.V.	14.4	15.9	18.7	24.0	20.5
LSD (0.05)	383.4	606.4	384.1	140.0	302.3

Table 4. International Soybean Program (INTSOY) variety evaluation experiment yields (kg/ha), yala season 1974, at two locations in Sri Lanka.

Variety	Gannoruwa (irrigated)	Gannoruwa (rainfed)	Alutharama (irrigated)
Jupiter	2,715.7	2,614.4	1,351.8
Hampton	2,508.4	3,002.8	1,599.0
Hardee	3,144.9	3,226.1	1,210.7
Improved Pelican	3,000.5	2,918.8	1,319.3
Bossier	2,811.8	2,982.5	1,070.9
Bragg	2,481.4	2,208.6	1,920.5
Davis	2,899.5	3,018.7	1,695.1
Tracy	1,996.7	1,892.9	1,586.5
Forrest	3,206.0	2,509.3	1,486.5
Hill	3,049.1	2,397.8	1,235.8
Clark 63	2,501.1	1,911.1	1,695.0
Bonus	2,277.0	1,611.0	1,340.1
Williams	2,231.8	2,094.1	1,545.6
Pb-1	3,166.3	2,645.5	1,288.4
S.J.-2	3,174.7	2,709.9	1,106.1

Table 5. Percentage analysis of protein and oil in soybeans tested in the 1973 INTSOY variety trials at six locations in Sri Lanka.

Variety	Parathan		Alutharama		Ratmalagara		Gannoruwa		Bandarawela		Maha Illuppallama	
	Protein	Oil	Protein	Oil	Protein	Oil	Protein	Oil	Protein	Oil	Protein	Oil
Davis	36.8	26.1	39.6	25.5	39.1	24.1	41.1	22.7	42.5	20.3	40.7	23.3
Hutton	40.7	24.8	42.2	23.8	38.4	25.8	40.3	23.8	45.1	18.4	43.7	22.4
Improved Pelican	38.4	26.8	40.1	24.5	37.7	27.3	42.9	23.0	45.6	19.3	42.4	22.9
Lee 68	37.0	26.8	42.1	23.8	36.8	25.1	42.0	23.6	45.6	17.7	42.6	22.7
Williams	40.4	26.2	42.2	23.8	38.2	25.8	41.0	24.2	46.7	18.3	41.7	23.7
Tainung R-1	38.6	23.4	40.5	23.5	39.7	23.6	43.3	22.8	45.6	17.0	42.7	21.1
Calland	37.0	27.3	40.5	22.9	36.1	24.9	40.8	22.5	44.5	18.9	39.1	24.0
Adelphia	37.7	25.6	37.3	24.9	37.1	25.0	39.8	23.2	41.2	19.1	38.4	24.5
Hardee	38.4	26.4	40.7	25.1	37.5	26.9	39.7	24.3	45.4	19.0	41.5	23.7
Hark	36.6	27.1	38.9	25.4	37.8	25.9	37.9	24.9	46.8	18.6	39.4	23.9
Harosoy 63	36.2	26.6	39.2	25.1	34.8	26.0	39.7	23.4	44.7	18.6	37.3	24.5
Bragg	37.8	26.9	40.4	23.4	36.4	26.5	38.5	23.8	45.1	18.5	41.7	23.6
Coker Hampton 266A	36.9	26.9	39.7	24.8	35.8	27.4	38.6	24.4	43.7	17.8	38.8	24.1
Jupiter	34.3	29.4	40.1	24.1	39.6	25.3	41.0	23.4	41.6	20.8	41.6	23.3
T.K.-5	38.9	25.0	39.1	24.3	40.8	22.8	44.2	20.4	45.0	17.3	43.1	21.5
Pb-1	39.7	22.6	42.8	21.1	40.1	21.6	43.1	20.4	48.5	15.1	44.3	19.9
Pickett 71	40.0	25.2	38.7	25.0	34.5	25.6	37.3	25.4	42.9	19.0	40.2	23.7
Semmes	39.2	26.0	39.6	25.5	35.0	27.7	41.2	25.1	44.8	19.2	40.7	25.1
Clark 63	36.8	27.5	40.1	25.0	38.7	24.3	38.8	23.8	45.6	10.0	39.5	24.8
S.J.-2	36.0	26.2	40.9	23.7	39.6	24.6	43.0	21.1	45.2	18.4	43.1	21.7

Two more locations were included for INTSOY (maha season 1973-1974), Bandarawela (altitude 4,300 m) and Parathan at a low elevation of 50 m.

Data from the protein and oil analysis (Table 5) brought out an interesting feature, in that the high-elevation location gave high protein values, ranging from approximately 41 percent to 48 percent and low values for oil content ranging from approximately 15 percent to 21 percent. The low-elevation station Parathan recorded high values for oil content ranging from approximately 22 percent to 29 percent and low values for protein content ranging from approximately 36 percent to 40 percent, with the combined value of about 63 for protein and oil for any one variety. (Thus we have an indication of where to grow our soybeans for high protein or where to grow them if soya oil is wanted.) Further studies will be carried out to check this gradation of protein content with elevation.

In the yala season 1974 trial we further tested the varietal suitability for rain-fed and irrigated conditions for one location. Most varieties recorded higher yields under irrigated conditions than under rainfed conditions. Forrest, S.J.-2, Pb-1, Hardee, and Improved Pelican did well under irrigated conditions while Hardee, Davis, and Hampton 266A performed best under rainfed conditions. Hardee and Davis gave almost equal grain yields under both conditions.

All varieties gave higher nodule counts under irrigated conditions except the variety Hampton 266A (Table 6). Dry weight of nodules was generally greater under irrigation than under rainfed conditions.

A coordinated soybean spacing trial was carried out in four locations in the yala season 1973 to determine the effect of spacing on yield of soybean. Spacings tested between rows were 30, 40, and 50 cm with 5 and 10 cm spacings within rows. Plant populations were as given in Table 7. Results showed that a spacing of 5 cms within the row gave significantly superior yields to 10 cm spacing within rows and that 30 cm and 40 cm spacings between rows were significantly superior to 50 cm spacings. Highest yield was 4,290 kg/ha, obtained with 40 cm X 5 cm (500,000 plants/ha).

Table 6. Nodulation data, International Soybean Program (INTSOY) variety evaluation experiment, yala season 1974, Gannoruwa, Sri Lanka.

Variety	Nodule Numbers[a]		Nodule dry weight[a] (gm)	
	Irrigated	Rainfed	Irrigated	Rainfed
Jupiter	605	467	2.254	2.260
Hampton 266A	393	314	2.193	2.078
Hardee	372	275	2.594	1.313
Improved Pelican	381	387	2.501	1.380
Bossier	493	403	2,908	1.233
Bragg	320	327	1.779	1.318
Davis	226	140	1.090	1.099
Tracy	271	224	2.038	1.673
Forrest	288	266	1.845	1.797
Hill	286	201	2.133	0.880
Clark 63	307	236	2.582	1.825
Bonus	242	90	1.658	0.636
Williams	251	254	2.423	2.315
Pb-1	332	273	2.663	1.176
S.J.-2	691	332	2.953	0.961

[a] Total of 10 plants at 3 weeks after first flowering.

In the coordinated soybean fertilizer trial (Table 8) where 20 kg/ha was applied with three levels of P and K fertilizer, in general there was a significant response to P at 60 kg/ha and an appreciable response to higher levels of P and K in the dry zone locations.

Table 7. Effect of spacing on yield (kg/ha), coordinated soybean spacing trial, yala season 1973, at four locations in Sri Lanka.

Treatment[a/]	Population (plants/ha)	Gannoruwa	Maha Illuppallama	Peradeniya	Alutharama
30cm x 5cm	666,666	2,488	2,629	3,808	4,250
30cm x 10cm	333,333	2,250	2,334	2,099	3,348
40cm x 5cm	500,000	2,864	2,276	3,194	4,290
40cm x 10cm	250,000	2,470	2,320	1,918	3,329
50cm x 5cm	400,000	2,608	2,411	2,699	3,643
50cm x 10cm	200,000	1,992	2,324	1,638	3,003
LSD (0.05)		327	--	--	391
C.V.		10.12	--	--	11.51

a/ Spacing between rows = 30, 40, and 50cm; spacing within row = 5 and 10 cm.

Table 8. Yields (kg/ha) in coordinated soybean fertilizer trial, yala season 1973, at four locations in Sri Lanka.

Treatment[a/]	Gannoruwa	Maha Illuppallama	Alutharama	Angunukulapalessa
N P0 K0	2,539	843	2,800	1,270
N P0 K1	2,359	1,199	2,915	1,563
N P0 K2	2,322	1,141	3,057	1,172
N P1 K0	2,611	974	3,287	1,270
N P1 K1	2,496	606	3,570	1,172
N P1 K2	2,304	944	3,601	1,466
N P2 K0	2,631	991	3,380	1,270
N P2 K1	3,019	1,200	3,730	1,368
N P2 K2	2,642	1,194	4,173	1,466
LSD (0.05)	411	--	598	not significant
C.V.	9.31	--	8.97	21.4
Treatment		Mean yield (kg/ha)		
P0	2,406	1,061	2,924	
P1	2,470	841	3,486	
P2	2,764	1,128	3,760	
LSD (0.05)	237	--	305	
K0	2,594	936	3,154	
K1	2,625	1,002	3,406	
K2	2,422	1,093	3,610	
LSD (0.05)	not significant	--	305	

a/ P205 (kg/ha) P1 = 30, P2 = 60. N = 20 kg/ha. K20 (kg/ha) K1 = 30, K2 = 60. Variety = T.K.-5.

Included in the IAEA program was an experiment to compare methods of application of fertilizer on growth and yield of soybean using P 33 (Table 9). The conclusions drawn from this experiment were as follows:

1. Starter N with or without addition of fertilizer phosphorus increased grain yields but the increase reached statistical significance only when P was added.

Table 9. Comparison of methods of application of fertilizer phosphorus on growth and yield of soybean (IAEA program) using P 33, yala season 1973, Maha Illuppallama, Sri Lanka.

Treatment	N (kg/ha)	P (kg/ha)	Phosphorus application method	Grain yield (kg/ha)	Straw yield (kg/ha)	Percentage P in grain derived from fertilizer
1	30	35	Surface broadcast and mixed in top 8 cm soil	2,116	4,370	47.3
2	30	35	Surface broadcast	1,960	4,243	44.3
3	30	35	Surface banded near seed	2,081	4,252	47.7
4	30	35	Banded at 4 cm below seed	1,951	3,998	43.0
5	30	35	Banded at 8 cm depth midway between rows	2,122	4,613	57.1
6	30	0	--	1,701	3,261	--
7	0	35	Surface broadcast and mixed in top 8 cm soil	1,819	3,700	49.6
8	0	0	--	1,605	2,888	--
LSD 1%				108	346	
C.V.				3.7	5.9	

Experimental details: Randomized block design, 6 replicates; plot size 2.25 m X 10 m, ridge and furrow layout, 45 cm X 5 cm spacing. All plots received K as basal dressing 50 kg K/ha. P 33 labelled superphosphate was used in a 0.09 m X 2 m subplot within the main plot. Variety used: T.K.-5, harvested just prior to leaf-fall. Soil test data: total N, 0.13 percent; NH_4 N, 3.0 ppm; NO_3 N, 21.0 ppm; available P, 8.1 ppm; pH 6.4.

2. Application of P midway between rows, broadcasting and mixing P on the surface, and surface banding near seed gave higher yields than surface broadcast and application below seed. Placement of P midway between rows gave the highest yields of straw and also the highest percentage P in grain derived from fertilizer.

(The higher uptake of fertilizer P in treatment 5 is probably due to the combined effect of a preferential orientation of roots towards the furrow, which region had a high moisture content resulting in greater dissolution of P granules.)

Two weed control trials were carried out in the two successive seasons, maha 1973-1974 and yala 1974. Results (Table 10) showed that the preemergent herbicides Linuron and Lasso proved to be satisfactory. Though the preplanting herbicide Planavin gave good weed control it showed phytotoxicity up to 20 to 30 percent. Nodulation was also low in this treatment.

Microbiological studies included experiments to determine the effect of inoculation and treatment with different levels of nitrogen, on the growth and yield of soybeans.

In the first experiment (Table 11) there was no response to inoculation at higher levels of N application. Response to inorganic N without inoculation was observed up to 40 lb N/acre. Response to inorganic N with inoculation was observed up to 20 lb N/acre.

In a study of the effect of fungicides, insecticides, and herbicides on nodulation the following chemicals were used: 0.25 percent Captan dust as the fungicide at a level of 1.5 oz/bu, 4 percent Malathion dust at 2 oz/bu as insecticide and Ramrod at 4.5 lb/acre in 40 gal water as the herbicide. Treated seeds were inoculated with the commercial product *Rhizobium*, "Nitragin-S," prior to planting.

Results showed that at recommended dosages these chemicals had no detrimental effect on nodulation (See Table 12). The fungicide, Captan at 1.5 oz/bu, increased seedling emergence.

A storage trial was conducted under three conditions of storage for 12 months (Table 13). Seeds were stored at 5°C, 25°C and room temperature using 10 varieties. It was found that up to 3 months, in all varieties germination of seeds was above 85 percent except Hardee, which showed 82.50 percent of 25°C, 77.75 percent at 5°C, and 76.50 percent at room temperature. Bragg at room temperature also showed 83.75 percent.

Table 10. Soybean yields (kg/ha) weed control trial, maha season 1973-1974 and yala season 1974, Gannoruwa, Sri Lanka.

Treatment	Maha 1973-1974[a/]	Yala 1974[b/]	Percentage weed control[c/] Maha 1973-74	Yala 1974
Hand weeded (at 2 and 4 wks)	1,891.58	2,782.57	90	71
Linuron	1,660.60	2,410.43	90	87
Diuron	1,596.76	2,442.93	47	77
Ramrod	1,552.56	2,169.88	83	69
Lasso	1,527.51	2,516.33	90	82
Vernam E-6	1,496.20	2,364.67	80	88
Planavin	1,154.43	2,493.86	63	93
Ramrod + Diuron	--	2,849.66	--	82
Unweeded	1,367.89	2,196.89	0	0
Hand weeded (weekly interval)	--	2,199.08	--	95
	Not significant	--		
C.V.	15.13%			

a/ Variety used = Cutler 71.
b/ Variety used = Bragg.
c/ At 5 weeks after planting.

Table 11. Effect on growth and yield of soybeans using inoculation and different levels of nitrogen.

	Inoculated with Nitragin					Uninoculated				
	Fertilizer nitrogen (lb N/acre)					Fertilizer nitrogen (lb N/acre)				
	0	20	40	80	160	0	20	40	80	160
No. of nodules[a/]										
Top root	5.32	3.97	5.02	5.6	2.72	4.4	3.32	3.9	2.37	2.35
Secondary roots	2.82	4.27	3.32	2.05	1.2	3.6	2.7	1.55	1.0	1.35
Oven dry wt. of nodules (gm)[a/]	.058	.04	.04	.04	.02	.04	.04	.03	.02	.02
Oven dry wt of tops (gm)[b/]	3.34	4.61	3.47	3.74	4.35	4.1	3.8	5.12	5.1	5.03
No. of pods/plant[c/]	11.05	19.6	18.5	20.9	17.2	15.2	14.6	19.9	16.9	18.8
Yield, kg/ha	2,414	2,794	2,421	2,596	2,626	2,240	2,352	2,613	2,434	2,593

[a/] Average of 40 plants.

[b/] Average of 24 plants.

[c/] Average of 20 plants.

Table 12. Effect of fungicides, insecticides, and herbicides on nodulation of soybeans.

	No. of nodules[a/] Tap root	No. of nodules[a/] Sec. root	Oven dry wt. of nodules[a/] (gm)	Dry wt. of tops (gm)	Yield (kg/ha)	Vacancies after 10 days from planting
Insecticide	17.4	8.2	0.23	30.94	3085	13.25
No insecticide	14.47	8.0	0.17	28.20	3206	21.06
Fungicide	14.75	8.1	0.18	27.65	3118	7.69
No fungicide	17.13	8.03	0.22	31.49	3175	26.62
Herbicide	16.78	7.97	0.18	27.64	3217	14.44
No herbicide	15.09	8.19	0.22	31.50	3075	19.87

[a/] Average of 40 plants.

[b/] Average of 24 plants.

Table 13. Effect of storage on germination of soybean seeds.

Variety	Mean Germination Percentage 5°C	25°C	Room Temperature
		Before Storage	
Improved Pelican	98.00	98.00	98.00
Hardee	96.00	96.00	96.00
Lee	65.00	65.00	65.00
Bragg	97.00	97.00	97.00
T.K.-5	100.00	100.00	100.00
T.E.-32	99.00	99.00	99.00
T.E.-26	100.00	100.00	100.00
Tainung(r)-1	100.00	100.00	100.00
S.J.-2	96.00	96.00	96.00
Pb-1	85.00	85.00	85.00
		3 months after storage	
Improved Pelican	85.75	84.50	86.00
Hardee	77.75	82.50	76.50
Lee	90.00	91.50	96.75
Bragg	89.25	89.00	83.75
T.K.-5	86.25	87.50	96.75
T.E.-32	94.00	97.25	92.75
T.E.-26	89.75	86.00	92.75
Tainung(r)-1	92.75	94.50	86.50
S.J.-2	88.25	90.75	95.75
Pb-1	97.00	97.00	95.00
		6 months after storage	
Improved Pelican	56.00	84.75	80.50
Hardee	59.60	65.00	52.75
Lee	40.50	67.75	71.75
Bragg	42.50	80.00	50.00
T.K.-5	47.50	88.50	49.25
T.E.-32	86.75	93.75	85.25
T.E.-26	92.75	90.00	59.75
Tainung(R)-1	92.75	90.00	77.75
S.J.-2	88.25	91.00	68.75
Pb-1	87.00	77.75	81.25
		9 months after storage	
Improved Pelican	62.25	75.50	60.75
Hardee	50.00	69.00	51.25
Lee	83.50	87.75	85.50
Bragg	48.00	52.25	39.75
T.K.-5	64.00	56.25	56.50
T.E.-32	71.00	64.50	59.50
T.E.-26	70.50	57.50	63.00
Tainung(R)-1	64.50	71.00	55.75
S.J.-2	86.25	72.75	72.75
Pb-1	88.00	73.00	66.00
		12 months after storage	
Improved Pelican	43.75	68.75	49.50
Hardee	57.75	69.25	50.50
Lee	66.00	75.00	50.25
Bragg	43.00	42.75	43.00
T.K.-5	80.00	81.50	70.00
T.E.-32	60.25	65.00	69.00
T.E.-26	64.25	41.00	52.50
Tainung(R)-1	50.25	56.25	50.75
S.J.-2	75.00	54.25	42.50
Pb-1	70.00	81.75	70.50

At 6 months all varieties except Hardee, Lee, and Tainung R-1 showed above 75 percent germination at the storage temperature of 25°C. At room temperature only the varieties Improved Pelican, Pb-1, T(R)-1, and T.E.-32 showed germination above 75 percent. At 5°C only T(R)-1, T.E.-32, T.E.-26, S.J.-2, and Pb-1 showed germination above 75 percent.

At 9 months all varieties showed germination below 75 percent under all three storage conditions except Lee, S.J.-2, and Pb-1 at 5°C, Improved Pelican and Lee at 25°C and Lee at room temperature.

At 12 months all varieties under all three conditions showed percentage germination below 75 percent except T.K.-5 and S.J.-2 at 5°C, Lee, T.K.-5 and Pb-1 at 25°C.

If the mean germination percentage of all varieties was considered, storage at 25°C was the best, showing 78.75 percent germination up to 6 months. Storage at 5°C showed 69 percent germination at 6 months while storage at room temperature showed 67.6 percent germination at 6 months.

Highlights of Soybean Production in Tanzania

E.T. Mmbaga

Soybean is a newly introduced crop in Tanzania and its potentials have not yet been exploited. However, the current trend is aimed at full maximization of the crop.

It was first introduced at Amani, Tanga, in 1907 by the Germans, and during the second World War (1939-1947) the British tried to grow soybean in West Lake Region but their efforts were in vain. The yields were terribly low due to poor varieties.

The potential of soybean was realized later and a breeding program was initiated in 1955 and completed successfully in 1963 at Nachingwea, which was a good target for soybean improvement after the failure of a groundnut scheme. Nachingwea varieties proved suitable for low altitudes. They have small seeds that have a high demand in the market, they are high yielders, resistant to lodging and shattering, and they are relatively free of diseases and mature in 115 to 125 days.

To obtain strains suitable for medium- and high-altitude areas, introductions were made from Kenya, Uganda, the United States and Colombia in 1969 and 1971. As Tanzania is divided into three altitude districts--that is, low, medium, and high--both exotic and indigenous varieties are being tested in the different altitudes in an attempt to select varieties adapted to each zone. Varieties that are still under evaluation are shown in Table 1.

Table 1. Soybean variety tests for adaptability to three altitude ranges in Tanzania.

Low Altitude (0-900 m)	Medium Altitude (900-1,500 m)	High Altitude $1,500^{+}$ m
(1) 3H/1	(1) Blyvoor white	(1) Hood
(2) 7H/101	(2) Bukura Purple	(2) H/1/1
(3) 1H/192	(3) Hokaido 48	(3) XB/1
(4) 3H/149/1	(4) Bossier	(4) Semmes
(5) 3H/9/2	(5) Improved Pelican	(5) Voorster
(6) 9H/100/5	(6) XB/2	(6) No. 19
Spacing: 10 x 75 cm	Spacing: 75 x 5 cm	Spacing: 60 x 12 cm

Soybean production is restricted to low altitudes simply because currently recommended varieties are adapted to this zone. However, not all lowland areas are engaged in soybean production; exceptions are Mtwara and Lindi regions in southern Tanzania which produce an appreciable amount of soybean, and also Morogoro region in the central part of the country. Sisal estates, state farms, Ujamaa villages and some schools within Morogoro are involved in extensive soybean production.

Seed multiplication farms whose responsibilities are bulking, multiplication, and distribution of seeds, are scattered over the country. Recommended seeding rate is 40 to 60 kg/ha, and fertilizer rate is 30 kg/ha N, 40 kg/ha P_2O_5 and K_2O. The time of planting varies with different geographical locations.

Diseases are not very serious. Moderate attacks of bacterial pustule, purple seed stain, mosaic virus, and root rot have been observed occasionally. Likewise, pests such as leaf-feeding beetles, pod-sucking bugs, pod borers, and leaf-sucking insects are not uncommon to some extent in a soybean field. For control, 20 to 100 ml of 35 percent endosulphan per 15 liters solosprayer are applied two to three times, especially at flowering and pod-filling stages.

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Harvesting of soybean includes both mechanical and hand methods. Mechanical means, e.g., combining, are especially used in seed multiplication and on state farms. Hand harvesting is the most common method in the villages. Plants are cut and threshed by using sticks. Soybeans are sometimes heaped on a mat or placed in a sack and then beaten with a stick. The yield ranges from 500 kg/ha to 2,900 kg/ha depending on quality of cultural practices.

General Agricultural Products Export Corporation (GAPEX) and National Milling Corporation are the two agents that buy all seed crops. These corporations are extremely dependable and, as a result, the farmers' interest in going into soybean production has been accelerated to some degree. To date, the price of soybean is Shs. 1.65 per kg but it is highly probable that this price will be higher in the 1974-1975 season.

Village soybean projects, United Nations Children's Fund, and nutrition extension services are the three main bodies involved in a campaign for better nutrition levels for the whole nation. Their approach is through education whereby nutritional requirements are revealed to the people, and then conveying the good news that soybeans can meet the daily protein requirements in their diets. Soy flour is at present being used in making porridge, at a ratio of one part soy flour to three parts maize flour. Breads of 10 percent soy flour and 90 percent wheat flour are common, especially in Morogoro region. Porridge and soymilk are generally used extensively in school feeding programs and the acceptability of these products is very high.

The processing of soybeans to soy flour is accomplished by using the locally existing mills. The farmers soak the soybeans for 6 to 12 hours and then boil the beans to eliminate the undesirable flavor. After boiling, the seeds are dried to 14 percent moisture before sending them to the mills, where the hull is removed and soy flour is processed.

Future prospects for the soybean in Tanzania are absolutely bright. Soybean uses fewer man-days compared to cotton, maize, coffee, and other main crops in Tanzania. Soybeans, through breeding, can be grown in all altitudes, which has never been the case for coffee, tea, and several other cash crops in the country. Furthermore, intercropping, which is a tradition in Tanzania, can utilize soybeans into the system successfully. The thing of greatest importance is to select varieties that can tolerate the canopy and at the same time give a considerably high grain yield.

Soybeans can fetch a very good market overseas and thus bring in foreign exchange. This is a national benefit and such golden wealth is to be tapped immediately. Primary sources of protein are limited in some parts of the country, especially in areas that are infested with tsetse fly. Thus soybean, which provides secondary protein, has an important role to play in improving people's nutritional level and eliminating malnutrition.

Lastly, soybean production calls for an industrial establishment in which soybean products can be used to formulate consumer goods such as baby foods, soy milk, soybean margarine and butter, soy beverages, and so forth. The by-products from industry can always find a market, either internally or externally. For instance, soybean meal and hulls can be used to feed the livestock. This means that more opportunities are opened for livestock improvement and for employment. The potentials of soybean are vivid, but the choice of going into production is entirely left to the farmers.

The Effect of Pedoclimatic Factors and Agronomic Practices on Soybean Performance in the Western State of Nigeria

T.I. Ashaye and
N.O. Afolabi

Soybean is an important crop of oriental origin. It was known in China before 2,200 B.C. The main world producers of the crop are the countries of eastern Asia (China, Japan, Manchuria), Russia, southern Europe, Brazil, Canada, and the United States.

Soybeans are produced primarily for oil and protein. The seeds of modern varieties have over 20 percent oil content and over 40 percent protein. This crop is one of the most important potential sources of protein and energy available for the human race. The value of soybeans, both for satisfying human dietary needs and for compounding livestock feeds, is just becoming appreciated in Nigeria. The levels of essential amino acids present in soybean compare favorably with those of fish meal (7). Leng (6) observed that soybean is almost unknown in Africa where protein is in acute short supply. It has been found that soybean meal at 750 naira per metric ton in poultry rations and partially (up to 40 percent) in pig rations.

Soybean History in Nigeria

Ezedinma (3) reviewed the history of the crop in Nigeria. According to him, soybean was introduced into Nigeria in 1908. An attempt to grow the crop at Moor Plantation at that time failed. In 1937, 10 new varieties were introduced from the United States, one from Malaya, and one from British Guyana. Of these, only one U.S. introduction (Oto otan), the Malayan, and Creole from British Guyana survived; the rest either failed to germinate or failed in the second year of planting due to poor handling. Between 1954 and 1960, the number of varieties in the Samaru collection increased from 38 to 60 (personal communication).

A number of varieties were introduced to Western Nigeria by the International Development Service Mission (IDS). There was hardly any trace of this latter collection by 1969. Gowen (5) reported that two variety collections--imported in 1960 and 1963--failed to germinate.

The success of the early introduction into Samaru in 1928 led to the introduction of the crop into other parts of Northern Nigeria. With the high demand for oilseeds during the second World War, the Malayan variety, which had a promising yield of over 1,100 kg per hectare, was rapidly multiplied and led to an initial export of 10 tons in 1947. Soybean soon became a cash crop in the Tiv division of Benue province. Its cultivation later extended to Ogoja and Abakaliki provinces of Eastern Nigeria. Recent inquiries showed that no stock could be purchased from there. There is an apparent need for extending areas of production to the higher rainfall zones in southern parts of Nigeria. In the recent years, the importance of soybean has been realized.

Soy-ogi, a recipe for solving nutritional problems, has been developed by the Federal Institute of Industrial Research, Oshodi (1). This offers far-reaching possibilities for increasing the protein level of Nigerian foodstuffs and products like those of the Akinrele group definitely have a good future in the agricultural development of the Western State of Nigeria. Detailed agronomic work on soybean started very recently. For quick results, it was decided to screen the available varieties for local adaptation. The trials reported here were initiated to study the pedoclimatic factors and agronomic practices that influence soybean performance in the Western State of Nigeria. It is hoped results will make it possible to evaluate the adaptation, yield potential, earliness to maturity, and disease and insect problems of some very good varieties and fit them to various ecological localities in the Western State of Nigeria.

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Location of Experiments

It is proposed to find varieties that are suitable for each part of the state. The experiments have been located in two sites as a beginning in order to be able to study in some details the soil factors, environmental effects, and agronomic practices. Fig. 1 is a map of the Western State with respect to the whole country. It also indicates the two sites in which the experiment was located. The variations in climatic parameters and soils are shown in Fig. 2, 3, 4, 5.

The soils of site A, Ikenne, are derived mainly from sandstones (sedimentary rocks) and the soils have been classified according to a system established by Moss (8). The soils are well drained, dark reddish brown friable humic clayey sand in the upper horizons and red sandy clay in the subsoils. The main clay type is kaolinite. The soils are usually very deep. Nutrient reserves are low. They however possess good physical qualities such as structure and texture. They are weakly acid in the surface soil but acidity increases with depth. Generally, stones, gravels, and concretions are few or absent. At a higher category of classification, the soil of the site would be grouped as a single unit--"ferrallitic tropical soils" (D'Hoore, 2). According to the classification of the U.S. Department of Agriculture (7th approximation), the soils would be placed in the great group of Oxisols (Smith, 9). They range between Nitosols and ferric Luvisols in the Food and Agriculture Organization (FAO) classification of 1973.

The climate of this site is typical moist monsoon with one to two dry months (January-February). There are two distinct humid seasons; the first begins with May and ends with July, and the second begins with September and ends with October. On the whole there are five wet (humid) months. The interruption of the humid season in August permits the harvesting of early sown crops under rather good conditions. The annual rainfall is 146 cm (57.70 inches) and exceeds the potential evapotranspiration (P^E) of 101 cm (40.4 inches). There is therefore always excess available moisture even when the rains have stopped. Annual maximum and minimum temperatures are 30.3^{o}C and 43.4^{o}C respectively. A day length of 12 h 20 min is exceeded for about 110 days in a year.

Site B, at Moor Plantation, lies within Vine's (10) climatic zone A, defined as having moderately strong, leached soils with low to medium humus content, weakly acid to neutral surface layers, and moderately strong, acid subsoil. The area lies within a single geographical unit, the "Ibadan group" described by Vine (10) as an area with friable, porous sands to sandy clays, commonly reddish in color. The soils are formed over basement complex. At higher orders of soil classification, the soils of the site would mainly be placed in the great group of Ultustalfs belonging to the suborder of Ustalfs in the order of Alfizols, or some may fall within the order of Oxizols. In the soil map of Africa, the soil of the area would be grouped as ferruginous tropical soils (D'Hoore, 2). According to the FAO classification of 1973 most of the soils will be regarded as Luvisols.

The climate of the zone is moist-dry monsoon (Guinea Savannah or Middle Belt) with one to three months dry (December-February) and six to seven humid months. (April-October). Average annual rainfall is 123 cm (49.2 inches) with equal potential evapotranspiration of 123 cm. The annual maximum and minimum temperatures for this zone are 30.7^{o}C and 21.4^{o}C respectively. A day length of 12 h 20 min is exceeded for about 115 days annually.

Varietal Testing

A rather moderate varietal testing program was started in the late season of 1972 at these two locations. Included in the trials were 16 varieties, most of which originated from the United States and for which enough seeds were available. But because of lateness in planting at Ikenne, quantitative evaluations on yields were not recorded for that site. The crop succeeded on Moor Plantation because of early planting. This paper reports late season 1972 and late season 1973 data for both sites. The 16 promising soybean varieties compared were: Improved Pelican, Bossier, Bienville, Roanoke, Semmes, CES 407, CES 486, Kent, Hood, Picket, Hawkeye, Hardee, Hale 3, Dare, Hampton, and IGM 7 Improved Pelican.

Cultural practices followed were similar to those generally used for maize (i.e., ploughing, disking and harrowing). Fertilizers were applied as basal dressing applied before the last harrowing at the rate of 30 kg/ha of each NPK element. There was no seed inoculation.

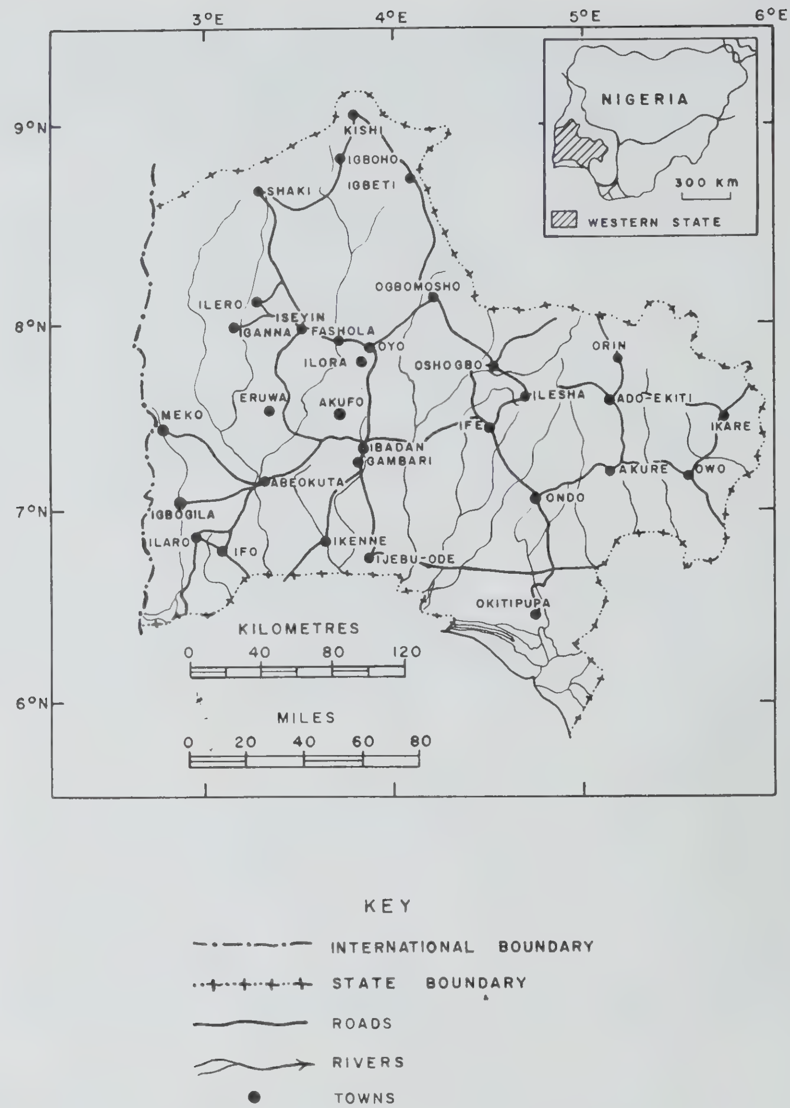

Fig. 1. Location map, Western State of Nigeria

Planting dates for Moor Plantation were 3 August 1972 and 31 July 1973, while the trial at Ikenne was planted on September 27. Individual plots consisted of four rows each, 4 m long and 40 cm wide. Three meters of the two center rows of each plot were harvested for yield determination. The tests were arranged as randomized complete blocks consisting of four replications. Records were kept on yield of seed per hectare, days to flower, date of maturity, plant height, and lodging.

RESULTS AND DISCUSSION OF YIELD TESTS

The mean yield data from the two locations are presented in Table 1, and the yield and other characteristics are presented in Tables 2 and 3.

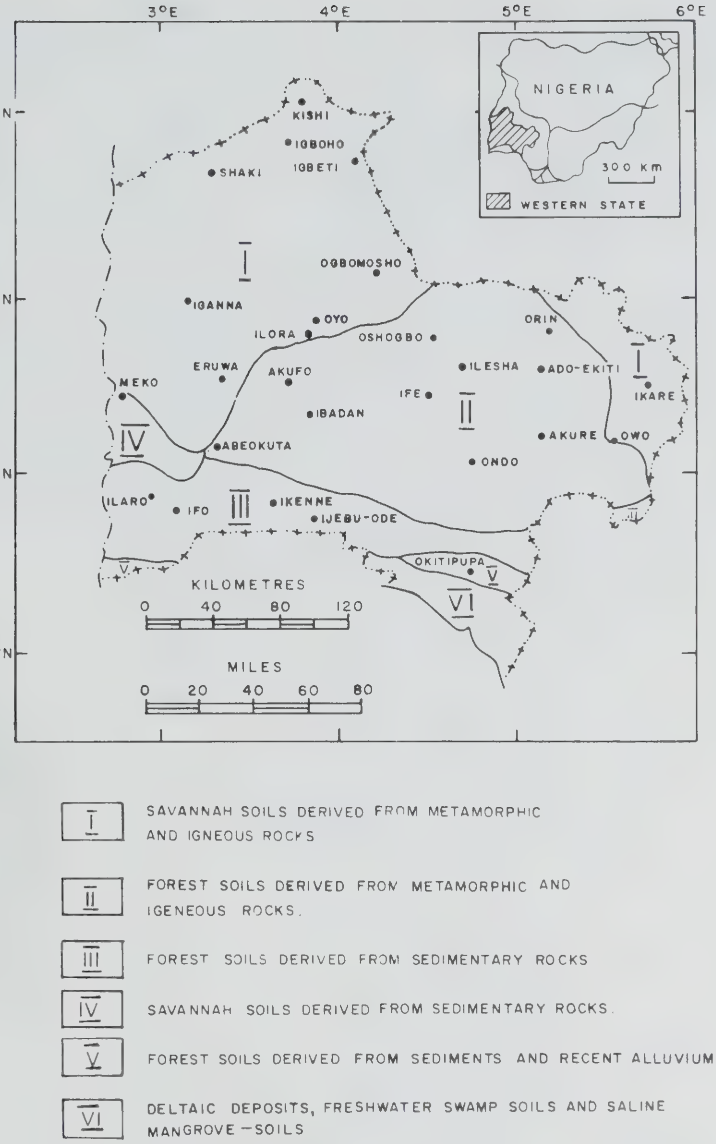

Fig. 2. Classification of soil zones, Western state of Nigeria.

Among the soybean varieties tested, Hale 3, Picket, Bossier, Hood, and Bienville gave yields over 2,000 kg/ha at Moor Plantation in 1972. In 1973, Bossier and Hardee produced consistently the highest yields at both locations (Table 1). At Moor Plantation, Hardee led with 2,435 kg/ha followed by Bossier with 2,164 kg/ha, whereas at Ikenne, Bossier and CES 407 topped the varieties with a yield of 2,646 kg/ha compared with Hardee 2,520 kg/ha. Apart from these two varieties, nine other varieties yielded 1,800 to 1,900 kg/ha at Moor Plantation.

There was no significant difference between the yields of the best varieties, Bossier and Hardee, and five other varieties. On average basis, for both sites, Bossier, Hardee, CES 407, and CES 486 appeared to be the best varieties with consistently high yields. The low yield obtained from CES 407 and 486 in 1972 was due partly to their susceptibility to fungal attack which resulted in premature defoliation. Poor germination appeared to be the main cause of low yield obtained from Hawkeye. Taller varieties represented by Hampton, Improved Pelican, CES 407, and CES 486 lodged more, as shown in Tables 2 and 3. This may militate against their selection when mechanical harvesting is being considered.

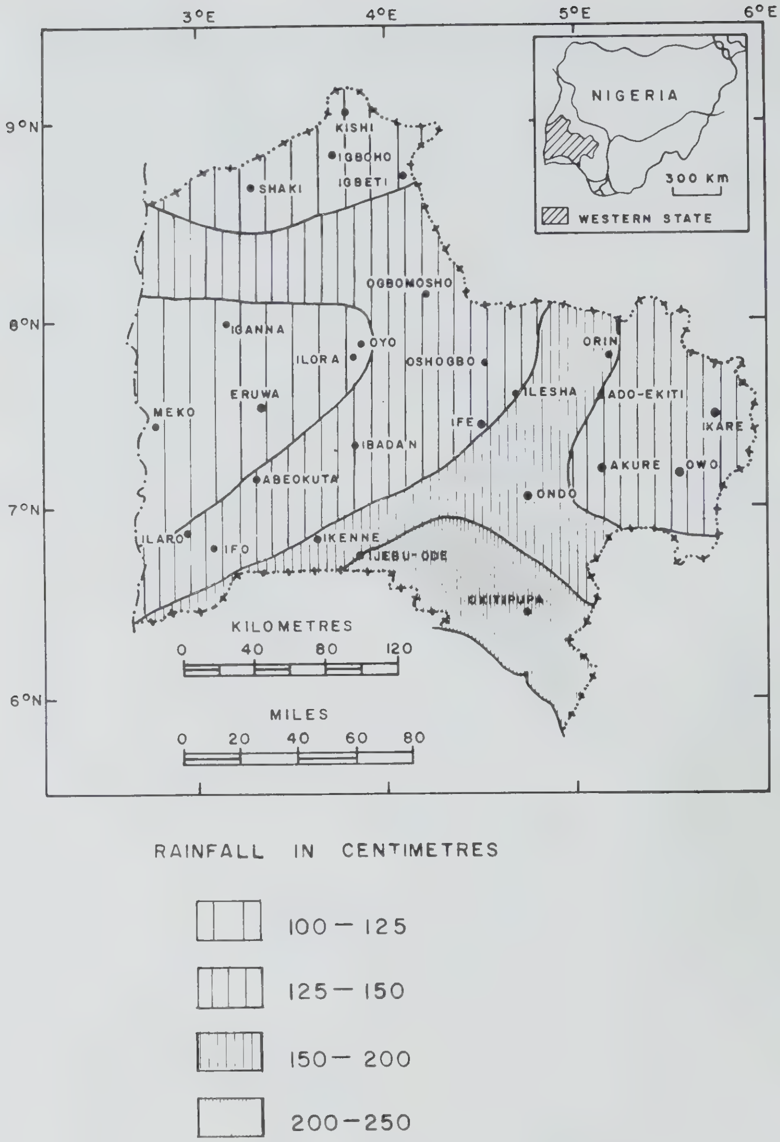

Fig. 3. Mean annual rainfall, Western State of Nigeria.

From the pedological point of view, it appeared that late-maturing varieties such as CES 486, CES 407, and Semmes are likely to do better at Ikenne (clayey loam soils) than at Moor Plantation (sandy clay soils). An explanation for this is that Ikenne soils, which are deep, clayey, well drained, and free from concretion have high capacity to retain moisture, permitting the roots of these tall, vigorous, late-maturing varieties to remain in contact with nutrients and moisture during the late pod filling stages. Whereas Ibadan soils are lighter in texture and drain more freely, the moisture levels in the soils drop rapidly and this adversely affects flowering and podding with resultant reduction in yield. The intermediate and early varieties yielded well at both locations. This can be explained by their short stature with lower requirement for moisture and the possibility of escaping drought stresses due to shorter maturity time.

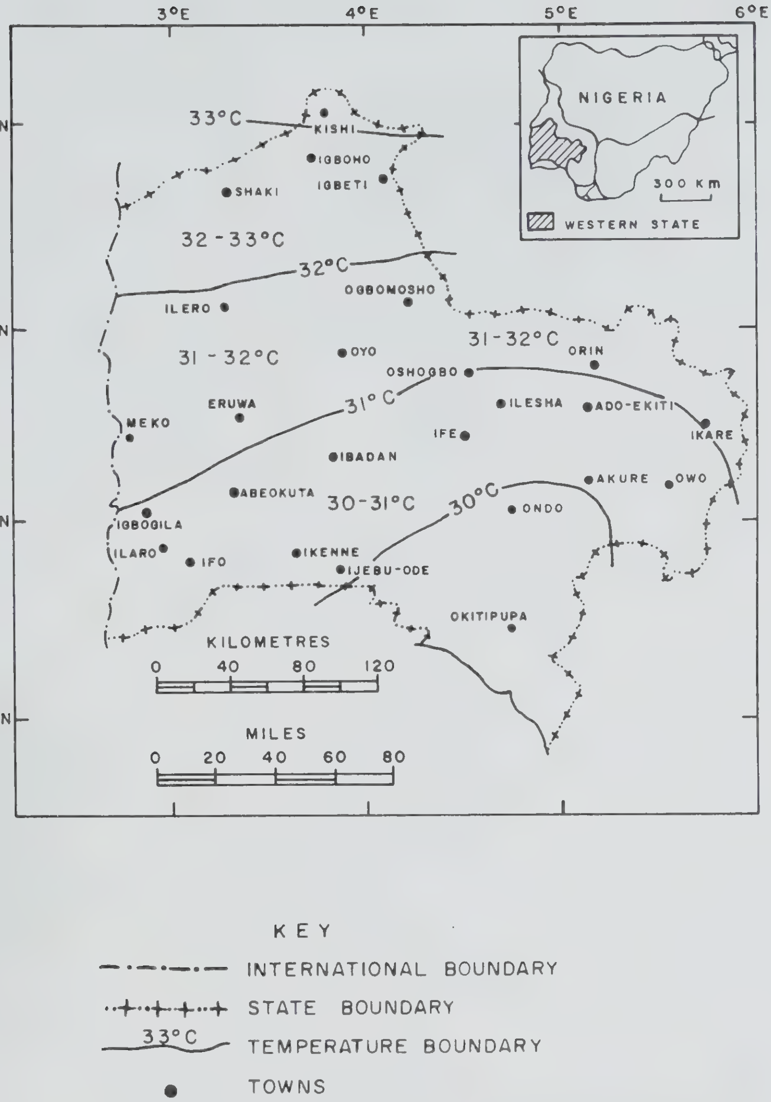

Fig. 4. Mean annual maximum temperature, Western State of Nigeria.

Climatological aspects of the two sites are different. Site A, Ikenne, has moist monsoon climate, whereas site B has moist-dry monsoon climate. The temperature ranges are about the same during the growing season. Site A has heavier rainfall and the potential evapotranspiration at this site is less than the annual rainfall. Thus, there is excess moisture in the soil even when the rainfall has stopped. At Moor Plantation, the annual rainfall is about the same as the potential evapotranspiration. This means that when the rain has stopped the moisture in the soil will be limited and crops will suffer due to high drought stress.

At Ikenne, the second humid season starts with September and ends with October. This permits late planting after early sown crops have been harvested under good weather conditions. Also, due to high water-holding capacity of the soils and low drought stress, a late sown crop also grows well and is harvested under good conditions. This appeared to be responsible for the overall yield advantage of most of the cultivars at Ikenne over those at Moor Plantation. In Table 3 the highest and lowest yields at Ikenne were 2,646 and 1,008 kg/ha compared with Moor Plantation 2,435 and 923 kg/ha respectively.

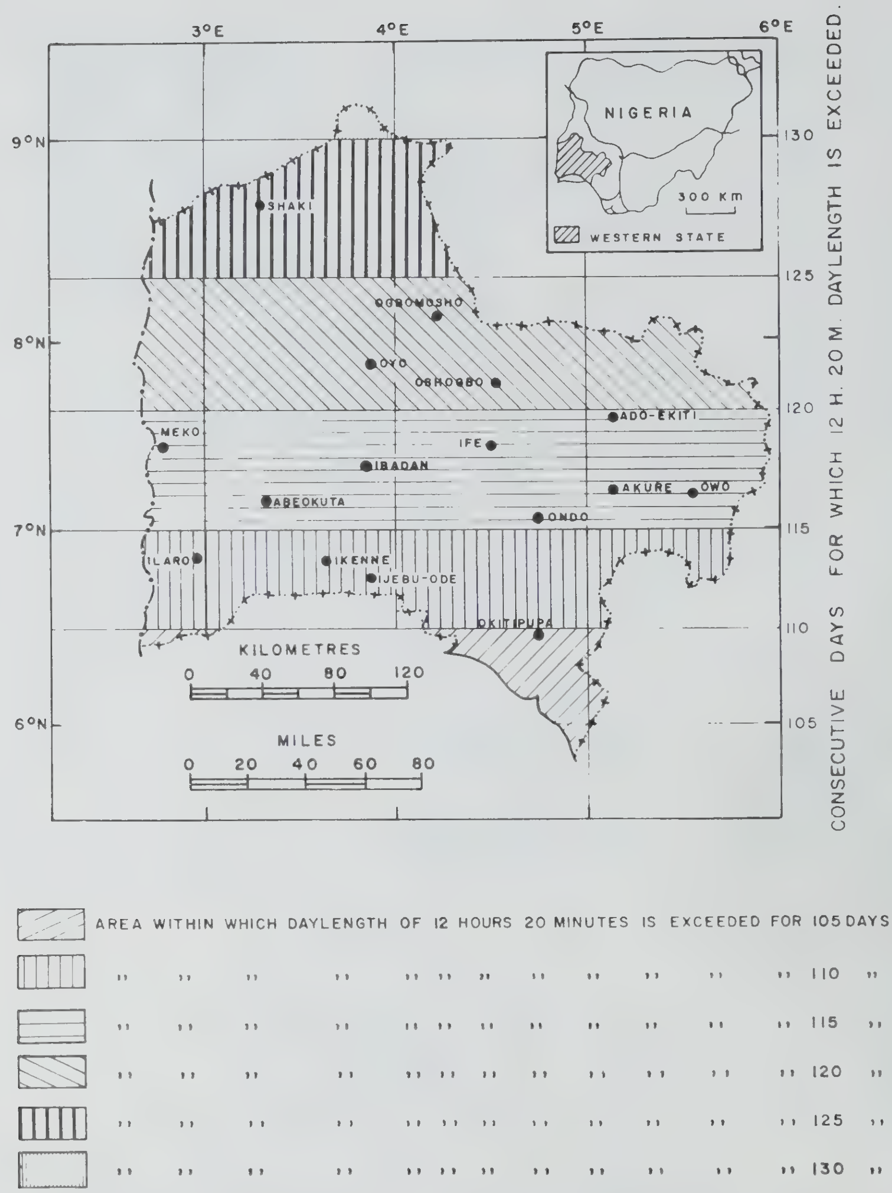

Fig. 5. Day-length distribution, Western State of Nigeria.

The results of these preliminary trials indicated that a yield of about 2,000 kg/ha can be obtained easily from some high yielding and ecologically adapted varieties (e.g., Bossier and Hardee). In terms of returns, this 2,000 kg should give about 400 kg of oil valued at 100.00 naira plus 1,300 kg of soybean meal valued at 400 naira for a total value of 500 naira per hectare. Farmers offered 200 naira per metric ton dry beans should earn 400 naira per hectare. Putting estimated cost of production at 200 naira per hectare, return to the farmer should be about 200 naira per hectare.

Improved cultural practices such as optimum fertilizer requirements reported by Goldsworthy and Heathcote (4) and optimum plant population when fully established should make for improved yields and better returns to the farmer.

Table 1. Summary of mean grain yields at 9 percent moisture content soybean varieties at Moor Plantation and Ikenne, Nigeria, 1973.

No.	Variety	Yield (kg/ha) Ikenne (Ijebu Remo)	Moor Plantation (Ibadan)
1	Hardee	2,520	2,435
2	Bossier	2,646	2,164
3	Hampton	1,449	1,936
4	Improved Pelican	1,764	1,935
5	IGM 7 Improved Pelican	1,890	1,900
6	CES 486	2,331	1,894
7	Bienville	2,457	1,892
8	Roanoke	1,764	1,849
9	Picket	1,449	1,834
10	Hale 3	1,764	1,833
11	CES 407	2,646	1,808
12	Hood	2,079	1,494
13	Kent	1,008	1,418
14	Dare	1,323	1,283
15	Semmes	2,394	1,208
16	Hawkeye	1,386	923
	Mean	1,844	1,738
	LSD (.01)	487.5	269.6
	C.V. %	14.05	7.62

Table 2. Performance of compared varieties of soybean at Moor Plantation, Ibadan, Nigeria, 1972.

No.	Variety	Yield (kg/ha)	Flowering (days)	Lodging score[a]	Maturity (days)	Height (cm)
1	Hardee	1,901.4	31	1.2	85	21.7
2	Bossier	2,052.7	29	1.2	85	29.8
3	Hampton	1,706.9	32	3.5	75	72.1
4	Improved Pelican	1,642.1	32	2.5	87	70.1
5	Improved Pelican IGM 7	1,642.1	32	2.5	87	90.6
6	CES 486	842.7	40	3.5	125	91.0
7	Bienville	2,020.3	35	1.5	87	35.3
8	Roanoke	1,663.8	35	1.5	87	29.6
9	Picket	2,182.3	31	1.1	85	21.8
10	Hale 3	2,279.6	28	1.1	90	29.1
11	CES 407	788.7	40	3.5	125	91.7
12	Hood	2,052.7	28	1.1	88	23.5
13	Kent	1,168.8	25	2.1	90	29.0
14	Dare	1,782.6	28	1.1	90	29.0
15	Semmes	1,642.1	29	1.2	87	33.9
16	Hawkeye	1,481.3	25	1.9	90	39.6
	Mean	1,678.0	31.67	1.89	91.53	46.99

a/ Lodging score 1 = erect, 5 = prostrate (2 = about 22.5° deviation from vertical position).

Table 3. Yield of grain and other characteristics of different varieties of soybeans at Ikenne (IK) and Moor Plantation (MP), Nigeria, 1973.

Variety group	Yield (kg/ha)		Days to flower		Days to maturity		Lodging[a/] score		Plant height (cm)	
	IK	MP	IK	MP	IK	MP	IK	MP	IK	MP
Early										
Hampton	1,449	1,936	30	32	78	75	2.5	3.5	72	72
Picket	1,449	1,834	30	31	83	85	1.0	1.1	25	22
Hale 3	1,512	1,833	27	28	89	90	1.5	1.1	33	30
Hood	2,079	1,494	27	28	89	88	1.0	1.1	25	24
Kent	1,008	1,418	26	25	87	88	1.2	2.1	48	43
Dare	1,323	1,283	28	28	91	88	1.0	1.1	30	29
Hawkeye	1,386	923	26	25	90	88	1.5	1.9	50	40
Intermediate										
Hardee	2,520	2,435	30	31	82	85	1.1	1.2	37	35
Bossier	2,646	2,164	30	29	81	85	1.0	1.2	36	45
Improved Pelican IGM 7	1,764	1,935	31	32	84	87	2.5	2.5	65	71
Improved Pelican	1,890	1,900	31	32	84	87	2.5	2.5	87	90
Bienville	2,457	1,892	33	35	84	87	1.2	1.5	46	35
Roanoke	1,764	1,849	32	35	84	87	1.1	1.3	50	30
Late										
CES 486	2,331	1,894	41	40	110	125	4.5	3.5	94	91
CES 407	2,646	1,808	41	40	110	125	4.5	3.5	95	92
Semmes	2,394	1,208	33	35	100	107	1.5	1.2	40	34

[a/] Lodging score: 1 = erect, 5 = prostrate (2 = about 22.5^{o} deviation from vertical position).

CONCLUSION

From the results of these trials, soybean production has a very high potential in Nigeria, especially for livestock feed concentrate. Varieties such as Bossier and Hardee appeared to have high yield potential for a wide range of soil and climatic conditions. While it is agreed that there is a need for testing a large number of varieties for adapting in various ecological zones, it appears that deep well-drained, friable, humic clayey soils would generally promote higher yields under adequate rainfall. There is no doubt that variety tests must still be carried out in other parts of the state under different soil, climatic, and environmental conditions and agronomic practices.

The next stage in experimentation would also involve the separation of the parameters already identified and their detailed study and assessment with regard to their degree of influence on soybean yields.

REFERENCES

1. Akinrele, I.A. et al. 1970. The development of soy-ogi, a corn based complete protein food. Research Report.

2. D'hoore, J. 1964. Soil map of Africa: explanation monograph. Pub. No. 93., Joint Proj. No. 11. C.C.T.A. Lagos, Nigeria.

3. Ezdinma, F.O.C. 1965. Some factors influencing the production of grain legumes in Southern Nigeria. Proc. 3rd Ann. Conf. Agr. Soc. of Nigeria. 4:48-50.

4. Goldsworthy, P.R., and Heathcote, R. 1965. Fertilizer trials with soya beans in Northern Nigeria. Samaru Res. Bull. No. 9, pp. 257-262.

5. Gowen, F.A. 1965. USAID final report, legume breeding programme. Ministry of Agr. and Nat. Resources. Moor Plantation, Ibadan, Nigeria.

6. Leng, E. 1969. The soyabean explores new territory. World Farming, pp. 8-15.

7. Morrison, F.B. 1956. Pages 1138-1139 in F.B. Morrison, Feeds and feeding. 22nd ed. Morrison Pub. Co., Ithaca, N.Y.

8. Moss, R.P. 1957. Report on the classification of the soils found over sedimentary rocks in Western Nigeria. Dept. Rpt. M.A.N.R., Ibadan, Nigeria.

9. Smith, G.D. 1965. Soil classification: a comprehensive system (7th Approx.). U.S. Dept. Agr. Washington, D.C.

10. Vine, H. 1954. Latosols of Nigeria. Proc. 2nd Int. African soils conference. Leopoldville, Congo.

Some Potentially Useful Mutants Induced by Ethyl Methanesulphonate in Soyabean *(Glycine max* L. Merrill)

C.K. Bulungu

In 1966 the Department of Crop Science, Makerere University, started soyabean research. The objectives have been, first, to improve the genotypes available to growers by means of selection from the assembled pool of varieties and by hybridization, and, second to examine critically all aspects of crop management suitable to the local conditions in East Africa. The results of the program have been reported (1, 3, 4, 6).

Soyabean improvement at Makerere is hampered by difficulties involved in making crosses. Moreover, strict quarantine regulations in East Africa limit the inflow of germ plasm to provide a broad genetic base necessary for crop improvement work. It was suggested, therefore, that experimental mutagenesis might provide a useful tool for the creation of the desired genetic variability.

Soyabean breeders in East Africa have not employed the induced mutation technique. This is understandable since there is a philosophy that breeders in developing countries should not use experimental mutagenesis on the grounds that the method is too expensive and too sophisticated (Krull and Borlaug, 2). And mutation breeders in developing countries have been accused of using the induced mutation technique haphazardly (Sigurbjornsson, 7).

We strongly believe that by using the experience gained by experienced mutation breeders in developed countries, the induced mutation technique can also be used together with the other breeding methods by breeders in East Africa. The cost involved in mutation breeding can be kept low by using chemical mutagens.

In September 1971 the author initiated a chemical mutagenesis program with ethyl methanesulphonate (EMS). Some of the potentially useful mutants induced are reported in this paper. Comparative studies on the effectiveness and efficiency of gamma rays and EMS, at comparable M_1 survival rates, have also been carried out and results are being analysed.

MATERIALS AND METHODS

Seeds of the soyabean variety Bukalasa-4 were treated with 0.00, 0.06, 0.12, 0.15, 0.5, and 1.0 percent solutions of EMS at 24°C for 16 h. Each treatment consisted of 360 seeds. The treatment solution was applied at approximately 3 ml per seed. After treatment the seeds were postwashed for 1 h in running tap water. Water adhering on postwashed seeds was quickly removed using blotting papers, after which the seeds were immediately sown in the field in September 1971. At harvest all M_1 plants were harvested, each plant separately. In March 1972 the M_2 generation was planted in M_1 families--that is, in a plant-to-row manner--and not more than 60 seeds were sown from any M_1 plant. All morphological mutants that could be identified in the M_2 were isolated. In October 1972 the isolated mutants were grown for confirmation in the M_3.

In April 1973 the confirmed mutants were carried to M_4. Selection was carried out in the M_4 using the selection criteria used for handling hybrids in successive generations in the Makerere soyabean program--namely, a high main stem node number, branches at a narrow angle to the main stem, nonshattering, nonlodging, plant height not less than 18 inches, reasonable clearance between ground level and the lowest borne pods, high number of pods, and resistance to bacterial pustule (Radley, 4).

In October 1973 the selected M_4 mutants were carried to M_5 to confirm their uniformity with respect to mutant type.

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Table 1. Genetic potential (mean ± *SE*) of some of the induced mutants of soyabean in comparison with Bukalasa-4 and Clark-63 (spacing: 50 cm X 50 cm).

Index number	Plant height (cm)	Height of lowest pod (cm)	Node number	Internode length (cm)	Number of branches per plant	Number of pods per plant	Number of seeds per plant	100-seed weight (gm)	Seed weight per plant (gm)
Bukalasa-4	46.2± 5.1	3.9±0.2	14.7±1.1	2.9±0.2	7.6±0.4	119.6±20.2	220.9±38.7	25.2±0.9	54.3± 9.8
Clark-63	29.9± 2.5	3.7±0.2	12.5±0.8	2.1±0.1	2.5±0.7	42.6±10.7	87.4±21.7	18.8±0.5	16.4+ 3.9
5	39.6± 2.2	4.4±0.4	13.6±0.8	2.6±0.1	7.5±0.8	102.9±13.3	210±7.32.9	21.2±3.0	43.3±17.7
8	39.1± 2.6	4.5±0.3	15.8±0.9	2.2±0.2	5.1±1.0	103.4± 8.2	222.1±29.1	21.4±0.5	47.0± 8.3
11	59.9± 6.8	4.1±0.7	18.2±1.3	3.1±0.2	7.7±1.1	151.7±24.9	283.6±46.2	18.6±1.1	53.4± 6.4
14	61.6± 5.1	3.6±0.5	16.2±0.6	3.6±0.3	8.0±0.7	161.1±39.1	293.2±47.2	18.3±0.4	53.7± 9.9
31	32.8± 0.9	3.5±0.4	12.7±0.2	2.3±0.1	5.9±0.5	97.0±13.9	191.7±10.4	23.2±0.9	44.1± 4.2
38	51.2± 5.9	3.8±0.3	16.5±1.1	2.9±0.2	7.3±0.7	171.2±23.1	313.2±58.8	23.0±0.8	70.2±13.1
40	72.8±13.0	4.1±0.1	20.6±1.5	3.3±0.4	8.0±0.5	184.2±31.0	337.3±91.8	25.7±0.4	84.9±22.3
41	70.6± 3.4	3.7±0.3	18.9±0.8	3.6±0.3	6.6±0.5	174.9±34.2	306.4±58.8	23.3±0.2	67.6±11.4
43	50.2± 6.3	4.6±0.3	15.1±0.8	3.1±0.4	8.4±0.4	250.2±30.0	440.0±25.4	22.7±0.7	100.3± 6.6

In March 1974, 28 uniform mutant lines were carried to M_6 and their "genetic" potential was evaluated in comparison with the parental variety Bukalasa-4. Clark-63, being at present the recommended among short and early varieties, was also included for comparison with the short mutants. The evaluation was carried out in a complete randomized block design with 10 replicates. In each replicate each line was sown in a single row 6 m long. The spacing used was 50 cm between rows and 50 cm within rows. At harvest, 10 plants from each row were used for measuring plant height, height of the lowest pod, node number, number of pods, number of seeds, number of branches, and seed weight. Measurements were taken on a single plant basis. For 100-seed weight, 100 seeds were selected at random from each replicate.

RESULTS AND DISCUSSION

Table 1 shows the most promising mutant lines induced in Bukalasa-4. Lines 5, 8, and 31 mature earlier than Bukalasa-4 but later than Clark-63. It can be seen that the three mutants have lower seed weight per plant than Bukalasa-4, but have higher seed weight per plant than Clark-63.

Lines 11 and 14 are nonshattering and with seed weight per plant comparable in magnitude with that of Bukalasa-4.

From the table it can be seen that changes in plant height were induced.

Mutants with increased number of pods, number of seeds, and seed weight per plant were also induced. Lines 38 and 43 seem to be particularly more promising since they have higher seed weight per plant without great changes in plant height in comparison to Bukalasa-4. Line 43 doubles the number of pods per plant, almost doubles the number of seeds per plant and seed weight per plant, in comparison with the parental variety. Lines 40 and 41, although having higher seed weight per plant than the parental variety, are unfortunately too tall, but could be used as parental lines in other mutagenesis experiments aimed at reducing their plant height while maintaining their high node number.

This season the mutants shown in the table are being evaluated in comparison with Bukalasa-4, Clark-63 and Congo-72 at low density (60 cm X 10 cm) and high density (40 cm X 8 cm) in order to reveal their economical value to the Uganda growers. Congo-72 has been included in this evaluation since it is now the recommended among tall varieties.

REFERENCES

1. Ashley, J. 1973. The status of soybeans in Uganda. Paper presented to Uganda Society of Agronomy, May 1973.

2. Krull, C.F., and N.E. Borlaug. 1970. The utilization of collections in plant breeding and production. Pages 427-439 _in_ Genetic resources in plants--their exploration and conservation. O.H. Frankel and E. Bennett, eds. International Biological Program Handbook No. 11.

3. Leakey, C.L.A., and P.R. Rubaihayo. 1970. Soyabeans as a potentially valuable crop for agricultural diversification in Central Uganda. E. Afr. Agr. For. J. 36:39-44.

4. Radley, R.W. 1971. Soyabean production. Paper presented to the FAO/UNICEF seminar. Kampala, Uganda.

5. Radley, R.W. 1971. Soyabean investigations at Makerere University, September 1970-August 1971. Paper presented to FAO/UNICEF seminar. Nairobi, Uganda.

6. Rubaihayo, P.R., and C.L.A. Leakey. 1970. Introduction, testing and selection of soyabeans in Uganda. E. Afr. Agr. For. J. 36:77-82.

7. Sigurbjornsson, B. 1967. Advances in breeding for better crops. IAEA, 1967.